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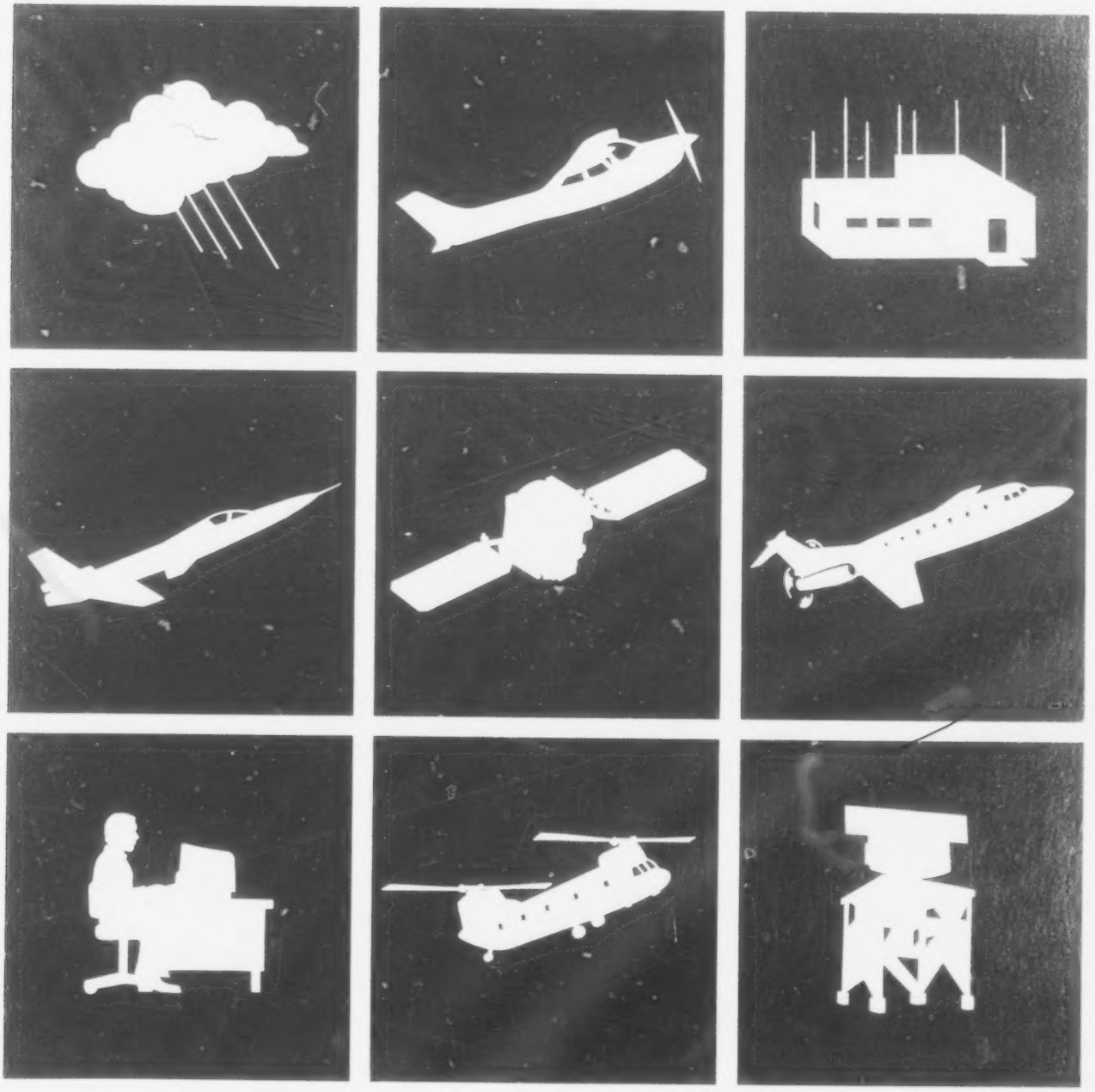
The Federal Aviation Administration Plan for Research, Engineering and Development

Volume I
Plan Overview

October 1985



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U.S Department
of Transportation

**Federal Aviation
Administration**

Office of the Administrator

800 Independence Ave., S.W.
Washington, D.C. 20591

This research, engineering and development (R,E&D) plan has been developed by the Federal Aviation Administration (FAA) to meet the challenges that face the National Airspace System (NAS) through the year 2010. We plan to capitalize on the capabilities provided by the implementation of the NAS Plan for Facilities and Equipment and more effectively meet the needs of all users of the system. The advanced technology aircraft envisioned for the future will add to the diversity of required services and may expand significantly the volume of the airspace included in the system. The ever increasing use of computers, both in the NAS and in the airplanes, portend an inevitable trend toward increased use of automation to improve system efficiency. An overview of the research and development activities needed to meet these challenges is provided in this plan.

The plan is focused on increasing NAS capacity and reducing delays; providing for flexible routes to increase user operating efficiencies; extending communications, navigation, and surveillance capabilities to meet user requirements; and improving the accuracy and accessibility of flight planning and aviation weather information. Developments are planned also in aviation security, aircraft safety, aviation medicine, and standards for airport construction, operation, and maintenance.

The expected benefits of this work are exciting. Certainly, the general aviation community will benefit from the extension of communications, navigation, and surveillance services and improved weather data. The prospects for the air-carrier user include increased NAS capacity, reduced delays, and more efficient flight paths. Several segments of the community will benefit from improved safety and capacity in oceanic airspace.

Future updates of this plan will reflect technology advances and results as they unfold. The next several decades of flight will present many challenges and opportunities for improvement. It is essential that the aviation community maintain a comprehensive and far-ranging program to capitalize on our collective talents and opportunities for advances in the efficiency and safety of our air transportation system.

Donald D. Engen
Administrator

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U.S. Department
of Transportation
**Federal Aviation
Administration**

The Federal Aviation Administration Plan for Research, Engineering and Development

Volume I
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Chapter 1
Introduction

This volume summarizes R,E&D activities in terms of user and system needs.

1.1
Plan Purpose and Scope

The Federal Aviation Administration (FAA) Plan for Research, Engineering and Development (R,E&D) describes a set of ordered and directed activities designed to improve the safety and efficiency of the National Airspace System (NAS). The goal of these activities is continued improvement of the NAS and continued U.S. leadership in aviation.

In 1981, the FAA initiated the NAS Plan, designed to modernize and improve air traffic control (ATC) and airway facilities services through the year 2000. This R,E&D Plan supports the NAS Plan and focuses on five principal areas for further improvements:

Capacity Improvements provided by the following:

Improved utilization of new and existing runway configurations based on reduced vehicle separation through the use of new communications, navigation, and surveillance (CNS) services; improved understanding of wake vortex behavior; and the development of procedures to increase efficiency of runway use in a safe manner.

Traffic management improvements to better match traffic demand to available capacity.

Time-based ATC techniques to accommodate and exploit aircraft four-dimensional (4D) navigation capabilities.

Airport surface traffic automation to aid in safely sequencing and routing traffic between active runways and gates.

Improved weather services to better measure and predict winds aloft, surface wind shifts, and significant storm activity.

Flexible Routing supported by the following:

The development of automated flight plan probes to reduce the controller workload associated with flexible routes.

Traffic management improvements to better ensure that aircraft operating on flexible routes are not diverted because of foreseeable traffic or airspace conflicts.

Integration of the traffic management and flight management functions of the ATC system into a flow management function that will provide conflict-free clearances to users for flight trajectories of their preference.

Extensions of CNS services to oceanic, low-altitude, offshore, remote, and urban areas.

Improved weather services to enhance the accuracy of long-term flight planning.

CNS Extensions based on the following:

Automatic dependent surveillance techniques for oceanic, low-altitude, offshore, and remote areas.

Use of the Global Positioning System for navigation in civil aviation.

The exploitation of satellite services for data link and independent cooperative surveillance.

Flexible precision approach guidance provided by the Microwave Landing System.

The development of services using the Mode S data link.

Weather Service Improvements based on the following:

Improved surface weather observations and winds aloft data, as well as new sensors for characterizing precipitation, and for identifying wind shear, turbulence, icing, and storm activity.

Development of more accurate weather forecasting.

New means of weather product distribution, including automated terminals, dissemination by data link, and direct access to centralized data bases to provide required information to flight specialists and airspace users in a timely fashion.

Flight Planning Service Improvements based on the following:

Availability of current weather information and forecasts along routes and at destinations of interest.

Availability of status information on airspace restrictions, delays, and NAS facilities.

The R,E&D projects designed to effect these improvements are divided into five categories:

- Direct Support of NAS Plan—projects that are specifically identified in the NAS Plan.
- NAS Enhancements—projects that would build directly on the facilities to be provided by the NAS Plan through the development of new procedures, extensions of NAS software and hardware, and the development of more accurate and accessible flight planning data bases.
- New Initiatives—projects that would apply new or emerging technologies and concepts. The results of these projects would primarily be applied after the year 2000.
- Sustaining R,E&D Activities—project activities that continue over long time periods in support of aviation security, aircraft safety, airports, and aviation medicine. These projects principally support certification and standards activities.
- System Studies—projects that would support the long-term evolution of the NAS through requirements definition, assessment of technical and procedural alternatives, and benefit studies. These efforts will lead to periodic updates of the R,E&D Plan, explore new concepts and technologies, and generate New Initiatives projects.

The purpose of Volume I of this two-volume plan is to describe the R,E&D Plan in terms of user and system needs. The purpose of Volume II is to describe the individual projects, grouped by technical area.

This plan is necessarily broad and long-range, both in the types of activities focused upon and in the time frames of activities, anticipated results, and expected applications. The time frames used are near term (1986-95), mid-term (1996-2005), and far term (2006-15).

1.2
R,E&D Plan Objectives

The R,E&D Plan objectives are to improve the NAS in the following ways:

- Increase capacity to meet increasing demand.
- Improve user and FAA productivity.
- Extend services to meet user needs for new services and for services in expanded regions of airspace.
- Maintain and, wherever possible, enhance the level of safety.
- Promote environmental protection.
- Ensure freedom of flight and flexibility in the use of airspace.

Today, major terminal areas experience capacity limitations. As a consequence, aircraft using these terminal areas and the adjacent en route airspace experience delays. As air traffic increases, delays will increase as well unless steps are taken to expand NAS capacity. Unfortunately, it is unlikely that a large number of new airports will be constructed; the principal challenge is to make better use of existing airports and airspace.

Demands for productivity in the NAS are intense. The FAA is under constant pressure to increase productivity as a means of controlling NAS operations and maintenance costs. Technology and procedural improvements that would provide an increase in productivity are continually examined. Air carriers in particular operate in a highly competitive environment, which naturally creates heavy demands for productivity. This industry segment has made substantial investments in new aircraft capable of more economical operation. NAS improvements will be pursued that will enable these aircraft to realize their operating efficiency.

The extension of services is a direct response to the increasing diversity of vehicle types and operations. For example, the expansion of rotorcraft operations requires the development of separation standards based on new CNS services in low-altitude, offshore, and remote area airspace. CNS for supersonic and hypersonic vehicles operating at very high altitudes would also require new CNS services.

The safety of aircraft operations in the NAS is well known and will be maintained as improvements are implemented. In addition, a number of enhancements are planned for purposes of directly improving safety, particularly with regard to timely dissemination of weather information.

Improvements related to environmental protection focus principally on reducing emissions of air and noise pollution. Modern aircraft have achieved significant improvements in these areas, and airport design standards have been developed that protect airport environs from aircraft noise emissions.

Finally, it is important to maintain freedom and flexibility in the use of airspace. It is not sufficient to meet the first five objectives by structuring and centrally controlling aircraft operations everywhere in the navigable airspace. The airspace is a national resource. Unencumbered access, consistent with the needs of users, must be maintained. In addition, military operations require substantial flexibility in the use of the airspace.

1.3
The National Airspace System

The NAS comprises airspace; ATC, communications, and surveillance facilities; navigation aids; procedures, rules, and regulations; aeronautical charts; technical information; and airmen and FAA personnel. Existing NAS equipment, procedures, and skills have evolved over 40 years, and without question represent the safest such system in the world. An overview of the services provided in the NAS is given in Chapter 2.

By any measure, operation of the NAS is a major undertaking. Approximately 250 commercial operators provide scheduled service to over 550 airports, enplaning over 300 million passengers per year. In addition, there are over 200,000 general aviation aircraft operating from nearly 16,000 landing areas. The NAS supports a broad spectrum of aircraft users, r. nging from scheduled and commuter air carriers to military, business aviation, general aviation, rotorcraft, and sports aviation users. These users operate a diverse array of vehicle types, ranging from balloons and ultralights to supersonic aircraft, and participate in a myriad of operations at vastly different speeds and altitudes.

Aeronautical research and technology initiatives underway today, notably in the areas of new materials and computer-aided design techniques, will spawn an even greater variety of vehicles in the future, especially at the high-performance end of the spectrum. New civil and military subsonic, supersonic, and hypersonic aircraft will emerge. In particular, the Aeronautical Policy Review Committee, established by the White House Office of Science and Technology Policy, foresees the emergence of a new generation of advanced subsonic air transport aircraft in the 1990s, with supersonic and hypersonic vehicles entering the NAS in the 21st century. These new vehicles will require new ATC techniques if full advantage is to be taken of their operating systems and efficiencies; their high-altitude flight envelopes will require extended CNS services.

1.4
The NAS Plan

In December 1981, the FAA chartered a comprehensive NAS Plan for modernizing and improving ATC and airway facilities services through the year 2000. The majority of FAA R,E&D activities over the next 2 to 5 years directly support this plan. Beyond this early time frame, R,E&D activities focus principally on new initiatives that build upon the foundation laid by the NAS Plan.

The improvements implemented by the NAS Plan will enhance the reliability and availability of NAS facilities and services. The plan also provides for facility consolidation and equipment modernization to reduce FAA operations and maintenance manpower requirements, as well as for controller automation aids to further enhance agency productivity. More important, the NAS Plan provides for a number of enhancements that will improve capacity, user productivity, and safety.

In particular, en route and terminal ATC functions will be consolidated and new functions will be added in the Advanced Automation System (AAS), to be installed in Area Control Facilities. For example, new en route functions will facilitate user-preferred trajectories and will improve safety by probing for aircraft and airspace conflicts along such trajectories. If conflicts are detected, these functions will alert controllers and provide effective resolutions that will minimize fuel consumption and delays. At the en route-terminal interface, metering functions will organize arriving traffic in accordance with terminal acceptance rates; if airborne delays are inevitable, they can be taken in high-altitude airspace for improved fuel efficiency.

Further, Mode S will provide an air-ground digital data link capability. Initial data link service will provide weather products from existing weather data bases on request to aircraft in flight. These weather data will enhance flight safety and user productivity by providing current information for flight planning.

The Microwave Landing System (MLS) will provide more flexible approach paths than does the existing Instrument Landing System (ILS). MLS will eventually support selectable glide slope angles and curved and segmented approaches to runways. These features will permit instrument approaches to separate short runways by Vertical Take-Off and Landing (VTOL), Short Take-Off and Landing (STOL), and general aviation aircraft, and will reduce landing minima at runways where ILS performance is the limiting factor.

The Flight Service Automation System (FSAS) will enhance flight safety and user productivity by improving the scope and quality of such data as weather, facilities status, and system delays available to users for flight planning. In addition, the FSAS will provide automated user access to these data bases via voice response systems and users' computer terminals.

The NAS Plan also includes a number of significant improvements to weather data collection, analysis, and distribution systems. These improvements will result in enhanced weather information for pilots and air traffic controllers. Two principal benefits will accrue—safer flight operations and improved user productivity through more reliable flight planning.

The planned extension of the Long Range Navigation (Loran C) network to fill the midcontinent gap will provide nonprecision approach guidance at a large number of airports that do not have such guidance today. These airports will then remain accessible in lower-visibility conditions, and the safety of operations will be improved.

1.5
Further NAS Improvements

In addition to a significant number of service improvements, the NAS Plan provides a foundation for further improvements to meet additional future requirements. Looking ahead to the year 2000 and beyond, advances in the fields of computer, communications, and satellite services may facilitate new and more automated control concepts, remove fixed-routing constraints throughout much of the airspace, and provide very high levels of system availability and reliability. The R,E&D Plan focuses on the following five areas for further NAS improvements:

- Capacity Improvements
- Flexible Routing
- CNS Extensions
- Weather Service Improvements
- Flight Planning Service Improvements

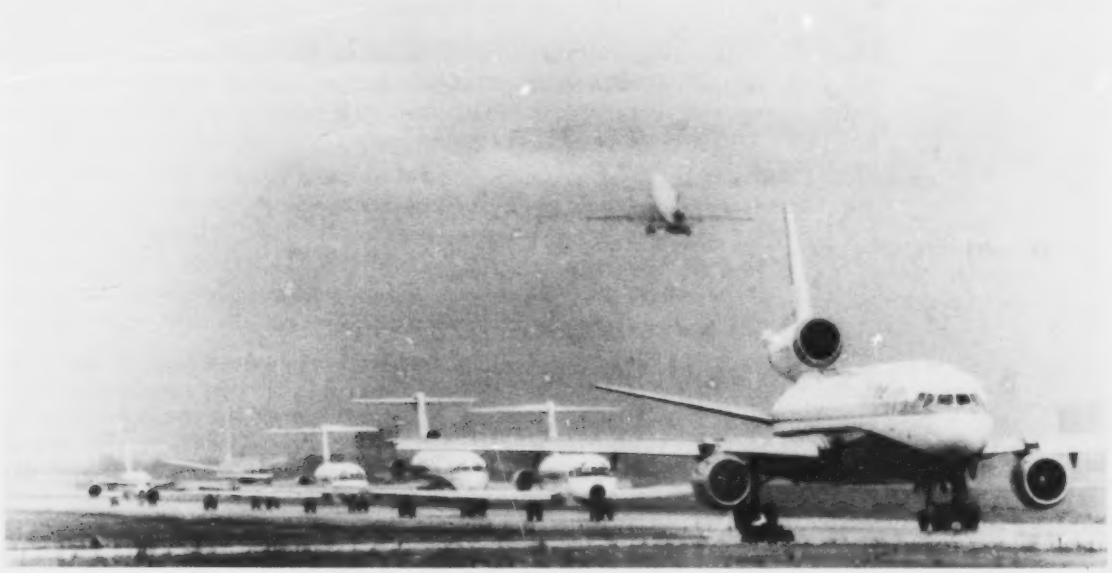
1.5.1
Capacity Improvements

A principal activity for improving system capacity and reducing delays is based on techniques for better utilization of new and existing runway configurations under Instrument Flight Rules (IFR). Opportunities for improvements include reduced longitudinal separations based on more accurate understanding of wake vortex behavior, and auxiliary CNS facilities to support IFR approaches to multiple runways in accordance with revised procedures.

A number of projects are focused on improved traffic management. The objective of traffic management is to match traffic demand to system capacity for achieving maximum utilization of available system capacity. Where delays are unavoidable, traffic management strives to minimize the associated costs, for example, by taking delays on the ground or at high altitudes to reduce fuel penalties.

Today's Traffic Management System is an automation tool distributed between the Central Flow Control Facility and Traffic Management Units installed in Air Route Traffic Control Centers (ARTCCs). It accepts system demand, capacity, and weather information, and generates a set of recommended traffic flow restrictions where necessary to distribute traffic demand geographically or over time. R,E&D projects in this area attempt to improve the scope and accuracy of input data provided to the Traffic Management System, and to generate additional advisory information for traffic managers and air traffic controllers.

Aircraft with 4D navigation capabilities can fly along prescribed or unspecified trajectories to arrive at designated points in space at designated times. When these aircraft can fly at their preferred altitudes and speeds, their fuel efficiency can be optimized. The R,E&D Plan includes efforts to develop time-based ATC techniques to accommodate aircraft with 4D capabilities. Initially, the objective is to relax ATC restrictions that prevent these aircraft from achieving their potential operational efficiencies. Later, the objective will be to

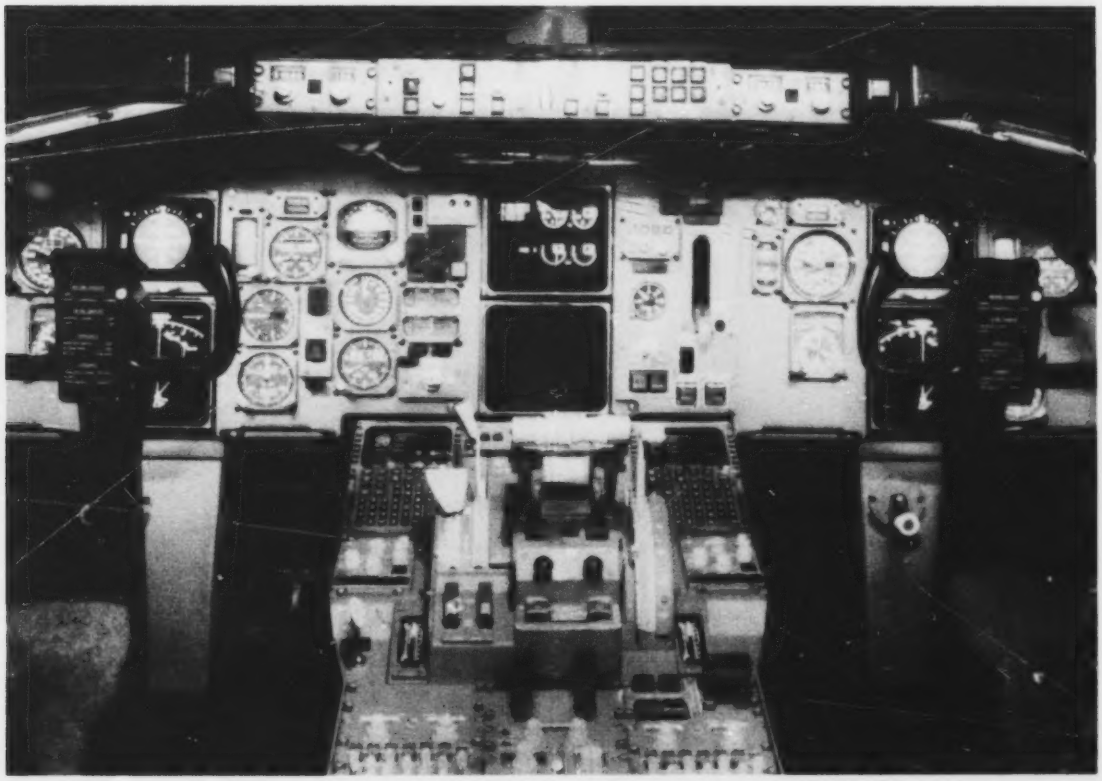


exploit the capabilities of 4D-equipped aircraft to improve estimates of future positions of these aircraft in the airspace, and to improve the accuracy with which interarrival times can be controlled at runway thresholds. Realization of this longer-term objective will contribute to the efficient utilization of available system capacity.

More efficient management of airport surface traffic will also improve system capacity, as well as the safety of aircraft operations on runways and taxiways. The development of airport surface traffic automation aids would encompass appropriate CNS techniques, traffic sequencing and routing methodologies, and guidance and control techniques.

1.5.2 Flexible Routing

There are three principal constraints on the extent to which users can operate on flexible routes in today's ATC system. The first is that current automation cannot determine whether or not a proposed flight plan is conflict-free from take-off to landing. Hence, an operator flying a direct route may encounter deviations due either to aircraft or airspace conflicts or to traffic flow restrictions. Second, CNS services required to support flexible routes are not available in much of the oceanic, low-altitude, offshore, remote area, and urban area airspace. Finally, today's weather information does not provide data with the accuracy required for routine operations along flexible routes, especially with respect to winds aloft, gust fronts, and storm activities.



The NAS Plan includes the development of automated probes in the en route environment. These probes extrapolate aircraft positions, based on their flight plans and the level of sophistication of their flight management computers, to detect aircraft and airspace conflicts, as well as conflicts with existing traffic flow restrictions. It is planned that, when fully developed, these probes will have automatic access, via digital air-ground data link, to flight path intentions (waypoints or headings) stored in aircraft 4D navigation and flight

management computers. If probes determine that a flight path deviation is warranted, an anticipated turn may be advanced or delayed, or the deviation may be implemented by transmission of an intermediate waypoint or series of waypoints to the aircraft. Following review by the flight crew, the waypoint(s) will be transferred to the navigation/flight management computer. Hence aircraft and ground computers would be interfaced over the digital data link to ensure fuel-efficient flight paths with minimum intervention by air traffic controllers and pilots. The coverage volume where these flexible routes are accommodated would be expanded in concert with extensions in CNS services, the application of dynamic special use airspace techniques, and user requirements for the increased airspace. It is anticipated that the extension of this capability to new airspace would attract users wishing to exploit the potential for faster, fuel-efficient flight.

New initiatives are planned that would couple the traffic management function more closely with the flight management function within the ATC system. In effect, the two functions would be integrated into a flow management system wherein the same data bases would be available to both functions, and their intentions and actions would be closely coordinated. As the traffic management and flight management functions are integrated into a flow management function, less intervention by the probes will be required since flow management will strive to provide conflict-free flight paths from take-off to landing.

1.5.3
CNS Extensions

The principal objective of the CNS extensions is to provide these services from the surface of the earth to at least 70,000 feet as dictated by user operational requirements. A secondary objective is to implement CNS technologies that can simplify user avionics requirements.

Surveillance extensions are focused on automatic dependent surveillance (ADS) techniques. In particular, it is envisioned that the aircraft position derived from the Global Positioning System (GPS), or the system that evolves from GPS, would be transmitted automatically to ATC facilities by data link to report the aircraft position periodically. The data link could be provided by satellite or could be a direct link from the aircraft to the ground. Earlier ADS implementations may be based on inertial navigation systems or Loran C. Independent cooperative surveillance via satellite will also be studied as a means for enhancing CNS system reliability in airspace where independent surveillance would not otherwise be available.

Navigation extensions are concentrated on the utilization of GPS by civil aviation. A number of studies are underway or planned to resolve pertinent reliability and integrity questions. At a minimum, it is expected that GPS will support en route navigation and will provide nonprecision approach guidance.

The objective of the communications extensions is to provide real-time access to real-time data bases, in particular, weather and flight planning information. Digital data link applications would be developed for transmitting weather data, airspace restrictions, delay information, and ATC clearances to aircraft. In turn, aircraft will provide ATC with winds aloft, flight intentions (e.g., waypoints), and automatic position reports (ADS). In the near term, Mode S ground stations will provide the data link. Later, satellite data link applications may be implemented, especially in oceanic environments and in other areas outside the coverage of Mode S ground stations.

The MLS will provide accurate guidance over more airspace (in the azimuth and elevation planes) than does the present ILS. This precision guidance will be exploited through the development of standards and procedures for performing approaches at various glide slope angles, performing curved and segmented approaches, performing short final approaches (e.g., for rotorcraft), and using precision missed-approach guidance.

1.5.4
Weather Service Improvements

Unanticipated weather events significantly degrade the ability to predict system capacity and to plan routes free of adverse weather conditions. It is planned that R,E&D efforts to improve weather observations, data analysis/ weather product generation, and product distribution will continue beyond the activities identified in the NAS Plan.

The Aviation Weather System development program relies upon cooperation between the FAA and other government agencies involved in weather activities, in particular the National Weather Service (NWS) and the National Oceanic and Atmospheric Administration (NOAA). In addition, joint programs such as the Next Generation Weather Radar, involving the Departments of Transportation, Commerce, and Defense, would provide detection of hazardous weather conditions and would meet the requirements of civil and military users for weather information.

Planned improvements in weather services, including wind shear detection using the Terminal Doppler Weather Radar and automated hazardous weather warnings, would provide new capabilities to enhance safety. The quality, accuracy, and frequency of routine weather data would be increased through automation and the use of improved sensors being developed by NOAA and NWS and supported by the FAA. New capabilities in this area include the measurement of cloud layer heights, the identification of types of precipitation, the measurement of upper atmospheric data, and the accurate location of gust fronts and storm activity. Improved data presentation for route weather briefings will be augmented by real-time weather services to airborne pilots. A centralized data base of all weather products will be developed, and is expected to evolve into a fully automated Aviation Weather System, accessible from the cockpit.

1.5.5
Flight Planning Service Improvements

Improvements in flight planning focus on the provision of data required by users, and the dissemination of these data before and during flight. Preflight route planning would make use of data on current or predicted delays, congestion, or airspace restrictions. The status of navigation facilities and airport facilities also would be available, as would the weather products discussed in the preceding section. Preflight data would be made available directly to users and to flight specialists.

In-flight, updated information could be requested by voice or by data link. Timely and accurate information would enable users to plan a response to changed conditions that would minimize delays.

1.6
Plan Organization

Chapter 2 of this volume describes principal NAS services, including ATC; communications; navigation and landing; surveillance; weather services; airport standards; aircraft, operator, and avionics certification; aviation medicine; and aviation security. It also summarizes user community needs for air carrier, general aviation, rotorcraft, and military operators, and briefly reviews FAA needs. Chapter 3 summarizes trends in aircraft operations and characteristics, airport operations, and NAS service trends. Chapter 4 summarizes the highlights of the R,E&D Plan and serves as an introduction to the more detailed project descriptions in Volume II. Chapter 5 presents a view of the NAS foreseen for the year 2010. Appendices to this volume include the rotorcraft perspective of the NAS, the military perspective, an advanced-technology aircraft description, a glossary, and an acronym list.

Chapter 2
NAS Services and Aviation Needs

A wide variety of airspace users have both common and unique requirements.

This chapter presents overviews of the principal services provided in the NAS; user needs within various categories (e.g., air carrier, military, general aviation); and provider (FAA) needs in operating and managing a safe and efficient NAS.

A number of efforts are underway within the government and in the aviation industry to project future aviation needs. The International Civil Aviation Organization (ICAO) Committee on Future Air Navigation Systems (FANS), for example, is defining aviation needs for the next 25 years, and is also evaluating technologies for meeting these needs. A Special Committee (SC-155) of the Radio Technical Commission for Aeronautics (RTCA) is studying future requirements of different user groups for communications, navigation, and surveillance (CNS), and the possible use of satellite technology for such applications. The National Airspace Review and the Transportation Review Board's Industry Task Force on Airport Capacity, as well as a few groups in other countries, are also addressing this issue. These studies have identified several improvements to the NAS that are of critical importance to user groups such as air carriers, the military, and general aviation. These improvements include, among others, increasing capacity at present or enhanced levels of safety, increasing user flexibility within the system, using integrated avionics to lower costs, and extending air traffic control (ATC) services to lower altitudes, remote areas, and oceanic airspace. Innovative concepts, such as increased use of automation and satellite systems, have also been proposed to meet user needs and to reduce the operating and maintenance costs of the FAA as service provider.

2.1
Overview of Principal NAS Services

The regions of airspace in which NAS services are provided can be divided roughly into three categories:

Line-of-sight airspace refers to the airspace within line-of-sight of CNS facilities installed on the ground. Within the majority of this airspace, separation service is provided utilizing ground-based radar. Aircraft receiving this service communicate with ATC facilities through ground-based communications equipment.

Low-altitude domestic airspace beneath the line-of-sight includes airspace in remote areas and offshore. Here, one or more of the CNS services from ground-based facilities may not be available because the line-of-sight to the associated ground facility is blocked by buildings, terrain, or the earth's curvature.

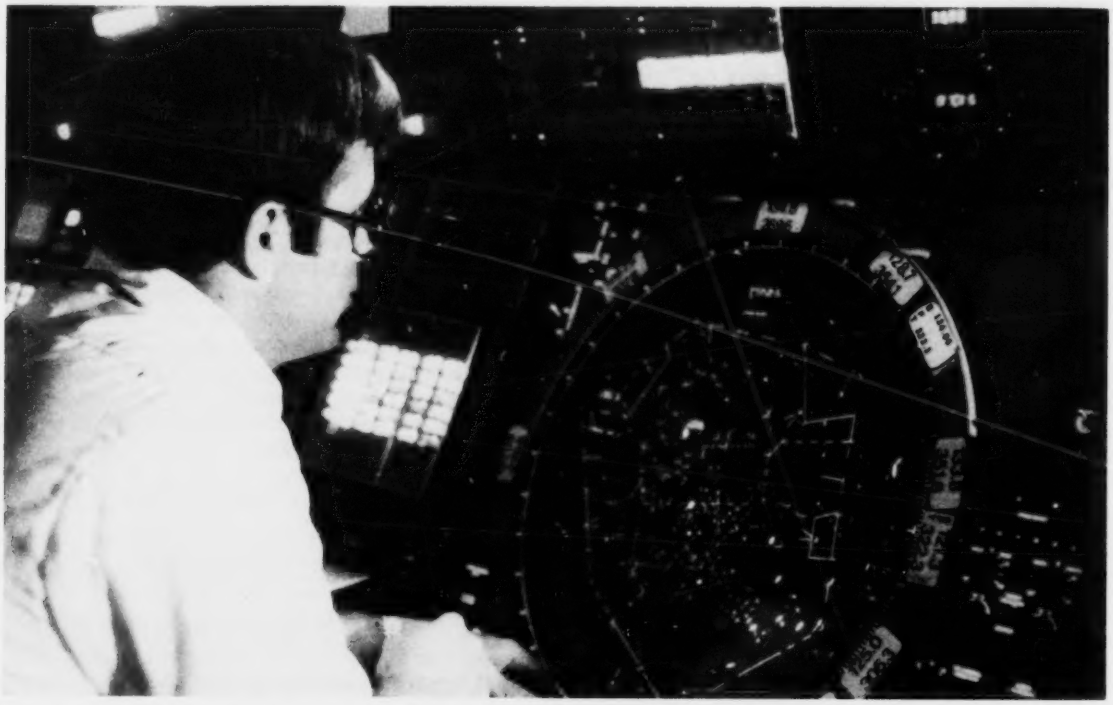
Oceanic airspace is beyond the domestic airspace. Some or all CNS services from ground-based facilities are not available because the distances are too great for the signal level, or because the line-of-sight is blocked by the earth's curvature.

The principal NAS services provided by the FAA to aircraft operating within these airspace regions include ATC; air-ground communications between the user and the FAA, and ground-ground communications between FAA facilities; navigation and landing; surveillance; weather; airport standards; aircraft, operator, and avionics certification; aviation medicine; and aviation security.

2.1.1
Air Traffic Control

The ATC service consists of traffic and flight management. Traffic management balances traffic demand with available system capacity at an aggregate level, ensuring that the controllers and runways can accommodate the volume of traffic through the airspace and at the airports. Flight plan information provided by users is the primary input in forecasting demand, while data on weather, airspace restrictions, and airport status are used to estimate current and future capacity.

Flight management provides flight planning assistance to individual flights, and provides separation services in flight. Flight planning is performed by aircraft operators with the assistance of flight planning services. Prior to a flight, an operator obtains a weather briefing describing the weather conditions along the planned route and a navaid status report describing the operational status of navaids along that route. When the operator has completed the planning for the flight, a flight plan may be filed to facilitate handling of the flight by traffic management and separation services, as well as to facilitate search and rescue operations in the event the



aircraft is later overdue at its destination. In providing the separation services, controllers, assisted by ATC computers, constantly monitor flight progress to identify potential aircraft-to-aircraft and aircraft-to-airspace conflicts. When potential conflicts are identified, routings or altitudes are revised to ensure that the appropriate standards for separation minima are met.

2.1.2 Communications

Two types of communications services are provided: air-ground exchanges with aircraft, and interfacility and intrafacility communications.

Air-ground exchanges are used by the pilot to obtain flight clearances; to report flight progress and weather observations such as wind shear and turbulence; to request position information in the event of emergency; and to obtain weather, airspace, and traffic advisory information. Today these exchanges are conducted by radio; in the future they will be conducted by data link as well as by radio.

The information exchanged among ground facilities includes flight plans, aircraft positions, traffic control coordination messages, clearances, weather products, navaid status, and equipment status for maintenance purposes. These exchanges contain both voice and data information.

2.1.3 Navigation and Landing

The navigation service provides the user with position information relative to a fix or earth coordinates (i.e., latitude and longitude). Guidance signals are derived in the aircraft that permit a pilot to steer along a planned flight path and to comply with clearances received from air traffic controllers. The precision with which an aircraft can follow a planned flight path with respect to intended flight route, altitude, and speed is the dominant factor in determining safe lateral spacings between air routes.

The steering information is derived from two types of navigation systems—point-to-point and area navigation:

In *point-to-point navigation*, the pilot follows a course with a fixed magnetic heading toward or away from ground-based radio navigational aids. These systems require simple avionics to obtain service.

Area navigation systems present information to the pilot so that a course can be flown between any two end points specified by the pilot. Steering guidance may be obtained with respect to the course defined by the two end points, or the range and bearing to the destination end point. Although the avionics are generally more costly than for point-to-point navigation systems, the system is more accurate and permits the user to select direct routes, with resultant fuel savings.

Two types of instrument approaches to the runway can be conducted—nonprecision and precision:

Nonprecision approaches are instrument approaches in which only lateral guidance is provided by landing systems and vertical guidance is obtained from the aircraft altimeter. The lateral guidance may be provided by an en route navaid, or by a landing aid when higher accuracy is required.

Precision approaches are instrument approaches in which lateral and vertical guidance and distance data with respect to the runway orientation are provided by special landing aids; lighting systems are also provided to assist the pilot in orientation during low-visibility and nighttime operations. The accuracy, reliability, and integrity of the landing aids and lighting systems determine the visibility conditions under which approaches can be conducted.

2.1.4 Surveillance

Surveillance provides the ATC system with an indication of the actual position of an aircraft. The aircraft position report is displayed to the controller so that a picture of the traffic environment can be obtained, and each specific flight path can be monitored to ensure separation. At present, the following methods of surveillance are used in ATC:

Primary Surveillance—A radar, called the primary surveillance radar, is used to determine independently the slant range and azimuth of the aircraft.

Secondary Surveillance—A transponder on board an aircraft is interrogated by a beacon radar, called the secondary surveillance radar, to determine slant range, azimuth, transponder code (i.e., identity), and reported altitude.

Dependent Surveillance—The pilot reports the aircraft's position when the aircraft overflies certain reporting points. In the future, this may be done continually through transmission via data link of the position as determined by the navigation system.

2.1.5 Weather Services

Acquisition, processing, and forecasting of weather data are primarily the responsibility of the National Weather Service and the National Oceanic and Atmospheric Administration. The FAA's primary role is the collection of weather data specifically related to aircraft operations and the dissemination of those data to air traffic controllers and aviation users. Pilots use weather information to determine when it is safe to fly, while controllers use this information to advise pilots and to estimate the impact of weather events on system capacity and safety. Weather is the single biggest contributor to airport delays and a major cause of aircraft accidents and incidents. Information on hazardous weather conditions, such as wind shear, gusts, thunderstorms, and poor visibility, is required by controllers and pilots for making departure and landing decisions. In addition, pilots need information on severe weather, turbulence, and icing for avoiding these hazards en route.

2.1.6
Airport Standards

Standards and guidelines are developed for the design, construction, operation, and maintenance of airports. These standards and guidelines pertain principally to the airport surface and encompass pavement construction; runway, runway exit, off-runway heliport, taxiway, apron, and gate configurations; firefighting and rescue methods; snow and ice control equipment and methods; airport surface lighting and visual guidance aids; bird and wildlife control; and detection and removal of runway surface contamination. Safety is ensured by means of guidelines for certifying airports that have demonstrated fire rescue capability consistent with regulations.

2.1.7
Certification of Aircraft, Operators, and Avionics

Aircraft certification addresses the airworthiness and crashworthiness of aircraft and onboard equipment, and the flammability and toxicity of materials used on aircraft. Pilots, aircraft operator practices, and pilot training programs are also certified. Avionics certification addresses the safe operation of this equipment and interfaces with other onboard equipment.

2.1.8
Aviation Medicine

In parallel with developments relating to facilities and procedures, the biomedical and human behavioral aspects of the evolving NAS are addressed by aviation medicine. Appropriate medical standards for airmen and agency personnel are developed. Other aviation medicine efforts address the impact of advances in technology; changes in the character, size, and roles of the airman and controller population; and the introduction of new equipment and procedures to ensure that the highest level of safety is retained for civil aviation. Of particular concern are the changing roles of pilots and controllers as increasing levels of automation are introduced.

2.1.9
Aviation Security

Equipment and related standards are developed to protect persons and property in the NAS against acts of criminal violence and aircraft piracy. Over two million passengers and their carry-on baggage are successfully screened for explosives and weapons each day in the U.S. Standards for concourse security are developed, as are procedures for responding to in-flight bomb threats.

2.2
User Community Needs

In general terms, all users want the flexibility to determine when and where they operate; they require safe operations with minimum constraints in all navigable airspace. While these and other needs are common to all users, many user needs are unique because of the special characteristics of aircraft and their missions.

The NAS currently accommodates 235,000 active civil and military aircraft. These include over 200,000 general aviation aircraft, over 4,500 aircraft used by air carriers and regional airlines, over 14,000 civil and military helicopters, and over 11,000 other military aircraft. As will be discussed in Chapter 3, the total fleet at the end of this century is expected to be nearly 312,000 aircraft; the number of passengers carried by airlines is expected to rise, and total take-offs, landings, and hours flown will all show an increase. In addition to this expansion in demand, new aircraft will be introduced capable of lateral and vertical translational flight, and the operating speeds of some of these aircraft will increase dramatically. They will exhibit preferred altitude profiles extending from near earth to at least 70,000 feet above mean sea level. Climb and descent capabilities will vary from a few hundred to 10,000 feet per minute. Differences in turn rates will be significant. Most, though not all, of these aircraft will need prepared landing and departure areas varying in length from tens of feet to more than 10,000 feet.

As users of NAS services, Department of Defense (DOD) aircraft rely on en route, terminal, and Flight Service Station services. These services often differ in nature from those provided to civil aircraft and occasionally require that the NAS "break stride" to accommodate military operations essential for readiness and the national defense. While the FAA is faced with the continuing challenge of meeting the myriad requirements of the civil community, it must also support military operations in behalf of the defense effort. The provision of airspace for special use by military aircraft, the accommodation of military exercises and high-performance aircraft, and other necessary services unique to military operations are essential to the DOD's ability to conduct its mission.

Apart from its role as a user and provider of NAS services, the DOD interfaces with the NAS on a wide scale that includes Air Defense activities, military command and control interfaces, the sharing of system resources, and the development of common procedures. Recognition of these interfaces is essential in the process of future NAS R,E&D planning.

In short, the magnitude of demand is steadily increasing, as is the variety of vehicle types and operations supported by the NAS. The resulting fundamental user need is for the NAS to accommodate the projected traffic increases safely and efficiently, and to permit each aircraft operator to take advantage of the unique characteristics of the vehicle in use.

The principal user groups are air carriers, including the regional airlines; general aviation (GA), including business aviation; rotorcraft operators; and the military. The subsections below address first the common and then the unique needs of these user groups.

2.2.1 Common User Needs

In spite of fundamental differences in their respective missions, all the user groups generally agree on the need for extended CNS services and improvements in weather services in the future NAS. The following points summarize particular common needs:

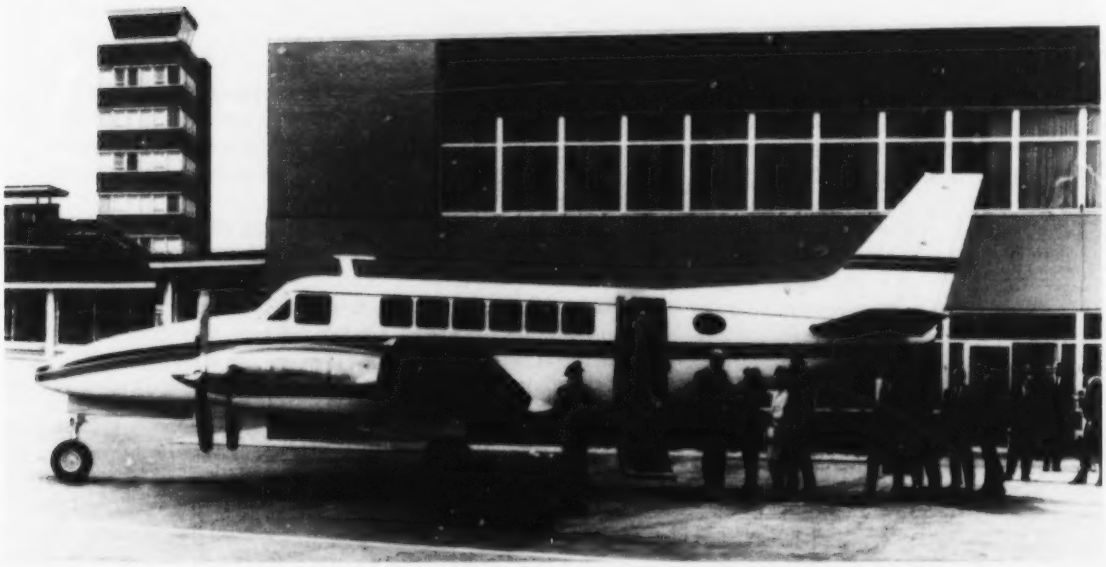
- All navigable airspace not specifically prohibited by national authorities should be available to civil aviation. Airspace so prohibited should be minimal and any constraints should be fully coordinated with users. Access should be denied only when and where a flight hazard exists; the ATC system should be designed on a basic premise that all navigable airspace is usable.
- The availability and integrity of NAS services must be high. The effects of any failure in service facilities should be minimal and should cause only minor degradation of system performance. Any degradation of performance should be fully defined and annunciated in real time to all users.
- Maintaining and, where possible, enhancing system safety must continue to be a primary objective of planners, designers, and operators of the NAS.
- Weather services should include an automatic advance warning about severe weather in the projected path of an aircraft. This warning should contain information on the severity of the expected weather, appropriate avoidance advisories, and information on the severity of weather on alternative paths. The warning should be issued in time for an orderly resolution of the severe weather hazard with minimal flight path alteration.
- The ATC system should provide the last known aircraft position, prevailing weather, and other pertinent information to search-and-rescue parties.
- All CNS systems should have appropriate backups so that essential services can be continued in the event of individual system failures.
- Procedures, standards, and certification for new aircraft, avionics, and technology are needed in a timely manner so that benefits can be obtained from the user investment.

2.2.2
Unique User Needs

2.2.2.1
Air Carrier Needs

The air carriers generally operate large, expensive jet aircraft equipped with sophisticated avionics. They fly fast and cruise at high altitudes. Operations are scheduled and competition is intense. In the near future, it is anticipated that a new generation of subsonic air transport aircraft will emerge, while supersonic and hypersonic air carrier aircraft may be commonplace in the early part of the 21st century. (These prospects are discussed in Appendix C.) The special needs of this user group can be summarized as follows:

- These users must have the ability to file and fly preferred, minimum-operating-cost trajectories on a routine basis. When a desired trajectory cannot be granted, or a revised one is desired, sufficient information should be provided to the operator to permit the development of a revised plan with ATC.
- Delays must be minimized and system capacity increased to accommodate projected growth in operations; more landing capacity is needed in high-density terminal areas.
- Modern aircraft capable of navigating to any point on the globe within seconds of the planned time should be able to utilize this capability to improve the productivity of their operations without artificial constraints imposed by ATC.
- All-weather operations are required at some airports to achieve a reliable service. These operations require navigation and landing aids with high accuracy, integrity, and reliability. In addition, all-weather guidance on the airport surface is needed.



- CNS services will be required to at least 70,000 feet altitude over domestic and oceanic airspace. The avionics necessary to obtain these services should be minimized, consistent with safety requirements.
- An airborne collision avoidance system should be made available as an independent backup to ground-based separation assurance services.

2.2.2.2 General Aviation Needs

General aviation encompasses many groups of users, from personal transport to business aviation. The equipment carried may range from the most sophisticated to the simplest; operations are conducted under Instrument and Visual Flight Rules. The needs of these groups can be summarized as follows:

- Flight planning assistance, including weather services, should be made readily accessible and easy to use.
- The avionics required to operate in the airspace should be minimized. Since the evolving NAS must accommodate the existing fleet for some time, current CNS systems should be retained, and the transition to any new capability requiring new avionics should be optional and based on perceived benefits.
- Single CNS avionics complements should be usable in most airspace.
- Navigation services should be extended to mountainous, remote, and low-altitude areas to permit improvements in operations.

2.2.2.3
Rotorcraft Needs

Modern rotorcraft are highly maneuverable and operate low-altitude missions that include intercity, intracity, suburban, and emergency medical service operations. The vehicle may be equipped for instrument flight. Special rotorcraft needs are summarized as follows on the basis of the perspective given in Appendix A:

- The extension of CNS services to near-the-ground is required in most airspace and most weather conditions. This service must be reliable so that both scheduled (e.g., airport-to-downtown area) and emergency operations can be performed.
- Access to airports should be provided via special corridors and landing areas so that rotorcraft operations can be conducted independently. Procedures and criteria should be developed to take advantage of the high maneuverability of the rotorcraft.

2.2.2.4 Military Needs

Over 90 percent of military missions within the NAS are for personnel training and emergency evacuation. The training missions include high-speed maneuvers at all altitudes in domestic and oceanic airspace. In some cases, the airspace is required only for a limited time interval, so that it can be shared by civil operators. Special military needs are summarized as follows on the basis of the perspective given in Appendix B:

- Special use airspace should be available as either fixed in time and space, variable in time and space, or fixed in space but variable in time.
- Access to civil airspace and airports is required whereby the military aircraft would be permitted to use military avionics for navigation, but communications and surveillance would continue to be common with the civil system.

2.3 Overview of FAA Needs

In addition to providing efficiently for the needs of users, the FAA's principal need is for increases in aviation safety and productivity. Examples of improvements in aviation safety, include hazardous weather avoidance, improved surveillance and separation monitoring, aviation security, crashworthiness, and aircraft and crew certification criteria. Examples of productivity improvements sought are facility consolidation, automation aids for the controller, and equipment modernization to reduce maintenance costs and manpower requirements.

Chapter 3
Trends in Aircraft and Airport Operations

The challenge will be to continue safe and efficient operation of the NAS in response to substantial growth in demand and advances in aircraft technology.

The NAS is the busiest and most complex airspace system in the world. The diversity of aircraft types and operations, both civil and military, results in differing demands on the system. Continuing growth in the number of aircraft operations, the diversity of operations, and the number of aircraft, as well as the introduction of new aircraft types, will impose unprecedented new demands. The safe and efficient operation of the NAS in the future is therefore dependent upon effective use of R,E&D activities that will provide a timely evolution of services in accordance with changing demands.

This chapter reviews trends in aircraft operations and characteristics, airport operations, and NAS services.

3.1
Aircraft Operations and Characteristics

Forecasts indicate that aviation activity will increase substantially over the next two decades. Table I presents anticipated NAS activity for the years 1990, 2000, and 2015. The demand for NAS services will grow with increases in the number of civil and military operations, enplanements, aircraft users, and fleet size. The subsections below summarize projected trends in operations and enplanements; aircraft hours, the fleet, and pilots; aircraft performance characteristics; and avionics.

Table I
NAS Activity Forecasts

Activity Measure	Actual	Forecasts		
	1984	1990	2000	2015
Aircraft Fleet (Thousands)				
Air Carrier	2.7	3.3	4.4	5.4
Commuter	1.5	2.0	2.9	3.6
General Aviation	213.3	235.0	287.0	317.0
Civil Helicopter	7.0	8.6	12.4	—
Military	18.8	20.2	20.2	20.2
Revenue Passengers (Millions)				
Air Carrier	336.4	417.7	605.7	1,010.5
Commuter	23.2	35.8	65.9	128.2
Hours Flown (Millions)				
Air Carrier	7.4	8.6	10.5	13.2
General Aviation	35.6	43.7	55.3	64.2
Military	5.9	6.6	6.8	6.8
Operations at FAA Facilities (Millions)				
Tower Operations	56.9	79.9	96.7	120.0
Instrument Operations	37.3	47.2	55.9	66.5
ARTCC Aircraft Handled	31.6	38.3	47.5	55.1
FSS Flight Services	54.8	71.7	87.5	101.6
Pilots (Thousands)				
Instrument-Rated	254.3	294.0	397.0	460.0
Total Pilots	718.0	791.2	950.4	1,025.0

3.1.1
Operations and Enplanements

Aircraft operations, including take-offs and landings at all towered and nontowered airports in the NAS, are anticipated to grow by 52 percent by the year 2000, with itinerant operations increasing 71 percent. Itinerant operations refer to those aircraft departing to or arriving from outside an airport's local operating area. Instrument operations in terminal areas as provided by an Air Route Traffic Control Center (ARTCC) or an FAA terminal approach control facility will increase by 50 percent. Flight Service Station (FSS) operations, including pilot briefings, flight plan originations, and aircraft contacted, will grow by 60 percent.

Air carrier domestic enplanements are expected to increase by 122 percent and commuter enplanements by 270 percent.

3.1.2
Aircraft Hours, the Fleet, and Pilots

By the year 2000, air carrier hours flown are forecast to increase by 42 percent, general aviation hours by 55 percent, and military hours by 15 percent. The number of air carrier aircraft will increase by 63 percent, commuter aircraft by 93 percent, general aviation by 35 percent, and the helicopter fleet by 77 percent.

The mix of the general aviation fleet will change dramatically during this period. The single-engine piston fleet, which normally operates on visual flight rules (VFR) below 12,000 feet, will increase from 168,000 to 205,000 aircraft. The more sophisticated twin-engine and turbine-powered aircraft will comprise the fastest-growing segment of the fixed-wing fleet, increasing from 33,000 to 59,000 aircraft.

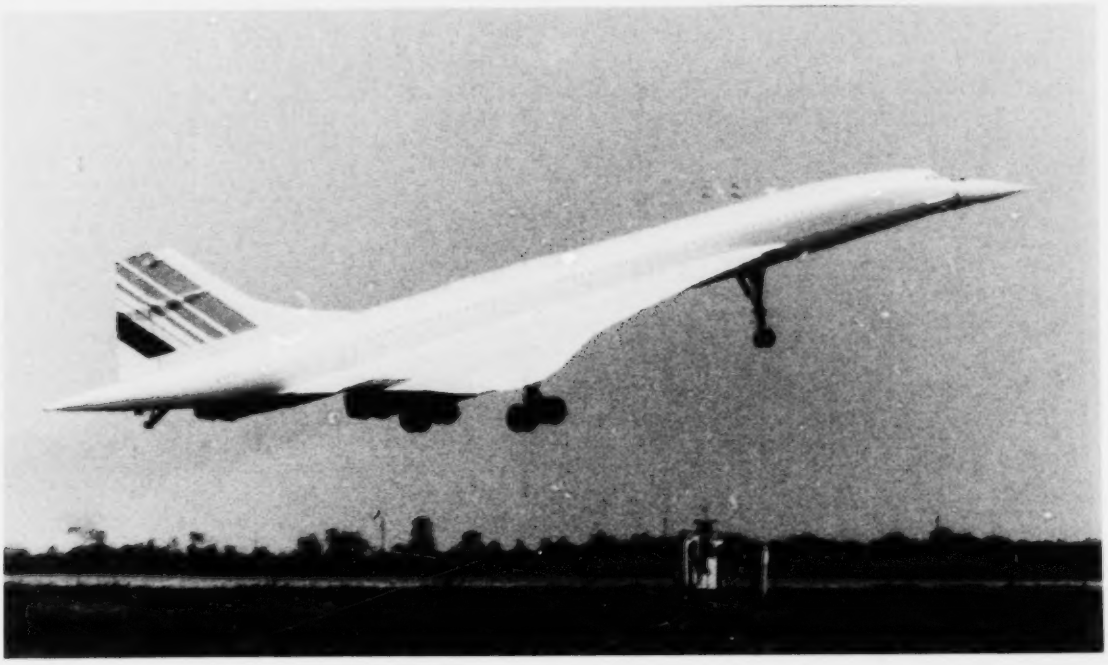
The number of pilots will increase by 32 percent. Those with instrument ratings will grow by 56 percent.

3.1.3
Aircraft Performance Characteristics

The expected range of performance characteristics for the various types of aircraft and rotorcraft operating in the NAS in the near term is shown in Table II. For the mid- and far terms, the trend for air carriers is expected to be toward aircraft designs offering greater fuel efficiency and the capability to operate at higher altitudes and expanded ranges with the same payloads. In the mid-term, a limited number of supersonic transports (SSTs) are forecast to enter the fleet, and by the year 2010, hypersonic, transatmospheric flights for both air carriers and the military are expected to be possible. For the general aviation/business aircraft community, expected trends are toward smaller aircraft operating at higher altitudes for greater fuel efficiency and range. Trends in future rotorcraft design include a greatly enhanced blade rotor design, leading to cruise speeds over 300 mph. These wide variations in aircraft operating characteristics will add to the complexity of ATC, especially in congested terminal areas.

Table II
Range of Aircraft Performance

Type of Aircraft	Near-Term (1986-1995)						Trend Forecast
	Cruise Speed (mph/mach)	Cruise Altitude (feet)	Range (S.M.)	Approach Speed (mph)	Takeoff Length (feet)	Landing Length (feet)	
Air Carriers	254/M0.8	10,000-65,000	700-6,000	85-175	2,700-11,000	1,880-7,000	For air carriers trend is towards aircraft with greater fuel efficiency operating at altitudes to 100,000 ft. and ranges to 10,000 miles. In the mid-term, there will be a limited number of SST flights. In the far term, hypersonic transatmospheric flights are possible.
General Aviation/ Business	120-300	5,000-40,000	300-1,500	50-90	1,300-3,000	1,200-3,000	For GA/business aircraft, the trend is toward smaller aircraft operating at higher altitudes for greater fuel efficiency.
Turbine-Powered Business	210/M0.8	8,000-55,000	1,200-5,000	90-160	1,800-5,600	1,500-4,000	
STOL	130/M0.7			50-90	600-2,300	700-1,700	
V/STOL	300/M0.9	50,000	to 2,000				
Rotary Wing	95-290	2,000-18,000	250-1,200				Advanced blade concept rotors will increase rotary wing speeds to 300 MPH.
Military Transport/Bomber	260/M0.8	10,000-65,000	1,500-5,000				A limited number of military SST flights and some hypersonic, transatmospheric cargo and reconnaissance flights are possible in the far term.
Attack/Fighters/ Reconnaissance	600/M2.0	to 100,000	70-750				
Training/Utility	200/M0.8	5,000-40,000	300-1,500				



3.1.4
Avionics Trends

Today, aircraft are equipped with a variety of communications, navigation, and surveillance (CNS) avionics. To a large extent, trends in CNS avionics will follow the development of new ground and satellite systems and the transitions to these systems:

- Trends in communications avionics are toward improving the reliability of the equipment and adding data link capability.
- Trends in navigation avionics are toward improving the reliability of the equipment, and implementing area navigation capabilities by integrating the navigation information from several ground, space, and airborne sensors. As satellite systems are developed and the costs of the associated avionics decrease, area navigation capability will become attractive to more users.
- Trends in surveillance avionics are toward increasing transponder equipage. It is expected that some avionics installations will provide an automatic dependent surveillance capability by transmitting the aircraft's navigation data for use by ATC.

3.2
Airport Operations

There are almost 16,000 landing areas in the United States, about 6,000 of which are open to the public. Today, civil airports handle about 126 million aircraft operations and enplane well over 336 million passengers annually.

In concert with increases in aircraft operations, airport activity will increase substantially by the year 2000. Accommodating this additional demand will become increasingly difficult. Although most of the nation's airports will have adequate airside capacity through the turn of the century, some of our key metropolitan areas are now congested, and more are expected to become so before the turn of the century. In some metropolitan areas, there is little or no reserve capacity, and the potential for airside expansion is limited. Though only a relatively small percentage of airports are involved, they handle a disproportionately high percentage of scheduled passengers; the 25 largest commercial airports enplane approximately 67 percent of all passengers.

The basic methods for meeting passenger air traffic demand in congested areas are as follows:

- The construction of new airports, new terminals, or new runways at existing airports—This approach can provide large incremental gains in capacity. However, establishing new major airports involves large financial, environmental, and land-use commitments. In addition, when new airports replace existing ones, large economic dislocations are likely to result. It is for these reasons that metropolitan areas, when faced with overcrowded airports, commonly seek alternatives to new construction.
- Encouragement to use aircraft with greater seating capacity—This approach has been a key factor in accommodating growth for the past 20 years. The average seating capacity of large commercial aircraft has grown from less than 50 in 1950 to about 150 today. A significant part of projected passenger growth will continue to be absorbed through the use of larger aircraft, together with the addition of more seats to existing aircraft and higher load factors. At large airports, the rate of passenger growth is currently about three times that of aircraft operations.
- New or improved runway and taxiway configurations at existing airports, together with revised ATC procedures and separation standards that will permit the use of these new configurations or better use of existing configurations.
- Terminal area traffic optimization, including the increased use of existing secondary airports within the hub and the addition of reliever airports.

This R,E&D Plan includes a number of projects designed to increase airport capacity by the third and fourth methods listed above (for existing airports, runways, and aircraft seating capacities).

3.3 NAS Service Trends

The types of services provided in the NAS in the near and mid-terms will be essentially the same as those provided today. However, more advanced technology will be used to provide these services more efficiently and safely. Foreseen NAS service trends include the increased use of automation; the extension of CNS services using automatic dependent surveillance and satellites; and the use of air-ground data link communications. It is planned that additional automation will be incorporated into the traffic and flight management services, and automatic dependent surveillance will support separation services in low-altitude domestic airspace, remote areas, and oceanic airspace. Data link will be provided between the aircraft and ground ATC facilities to permit increased levels of unambiguous communications, improved efficiency of in-flight planning, and automatic transmission of flight safety advisory information. Satellites may provide CNS services to low-altitude domestic airspace, remote areas, and oceanic airspace, and are expected to permit the development of instrument approaches to runways not equipped with the Instrument Landing System (ILS) or Microwave Landing System (MLS).

In the far term, some NAS services may be radically different from those provided today because of substantially different requirements from those encountered today. An example is user-preferred trajectories, optimized for fuel efficiency for supersonic and hypersonic aircraft. Future services may also change to exploit bold new technologies, such as the application of expert systems to ATC and to aircraft flight control systems.

Chapter 4
R,E&D Plan Description

The plan contains a broad spectrum of projects focused on user needs.

This chapter describes the R,E&D Plan. This plan is specifically designed first to support and then to build upon the foundation provided by the NAS Plan. The discussion below explains some issues addressed in designing the R,E&D Plan, and then summarizes the plan in five project categories.

4.1
Issues Addressed in Designing the R,E&D Plan

A large number of detailed technical and operational issues must be addressed in carrying forward an R,E&D program that supports an efficient evolution of the NAS. These issues can be expected to yield to the diligent efforts of technologists and operational specialists; they are not substantial impediments to progress.

There are, however, a number of institutional issues that can impede progress. The resolution of these issues is in the domain of the R,E&D program, although solutions may not be as straightforward as those for the technical and operational issues. This section describes how the R,E&D Plan is designed to deal with two principal institutional issues.

4.1.1
Community Consensus on NAS Evolution

Not every user in the national aviation community has the same set of objectives. This is a natural consequence of the wide diversity of vehicle types and flight operations. For example, some users may seek maximum freedom in the use of certain airspace with essentially no constraints imposed by a traffic control authority. Other users may urge a careful structuring of flight operations in the same airspace as a means of achieving higher capacities and more efficient flight operations. Experience shows that rapid progress can be achieved when there is community unanimity on development objectives; however, differences in user objectives often prevent such unanimity.

An effective way of ensuring reasonable progress in spite of the disparity in user views would be to conduct NAS R,E&D activities in close coordination with the user community. Such coordination will enhance opportunities for reconciling user needs with the planned system evolution. Users will be informed of the foreseen requirements for NAS improvements, as well as the technical and operational opportunities identified for meeting those requirements, and their comments will be solicited on the alternatives selected for development. Chapter 2 of Volume II describes a NAS R,E&D planning process that includes system studies projects intended to solicit user participation through close coordination with the aviation community.

4.1.2
Achieving NAS Improvements on a Timely Basis

It takes time to implement improvements in the NAS; the time period from concept definition to initial operational application can be measured in years. A principal reason for this is the unique combination of technical and operational practices that comprise the NAS. Improvements require not only technical development and proof, but operational development and proof as well to ensure that new capabilities can be integrated effectively into the NAS.

Before an improvement can be implemented, an R,E&D project may be required to support the development of any or all of the following products: a ground facility specification; Minimum Operational Performance Standards for avionics; draft guidance for avionics certification; draft guidance for constructing approaches, departures, and airways based on the intended improvement; and draft controller procedures. In addition, the proof of these products typically requires an appropriate operational validation that may involve avionics installation approvals, the development and approval of flight crew operational procedures and associated training programs, and the development of controller training programs for test and evaluation purposes.

The best assurance of timely accomplishment of an R,E&D project and timely implementation of the associated NAS improvement is comprehensive planning of all project elements at the outset, as well as adequate coordination of project schedules with agency offices and the user community to ensure that all required activities are included. In the project plan descriptions provided in Volume II, an attempt is made to define the full range of activities required to accomplish the associated technical and operational developments.

4.2
Project Categories

The remainder of this chapter describes the R,E&D Plan in five categories:

- Direct Support of the NAS Plan
- NAS Enhancements
- New Initiatives
- Sustaining R,E&D Activities
- System Studies

The first category, Direct Support of the NAS Plan, consists of near-term projects that are required to implement the NAS Plan within established time and cost constraints. In addition, some of these projects contain enhancements that go beyond the NAS Plan, but that do not comprise the major part of the project.

The second category, NAS Enhancements, consists of projects that will provide additional capabilities made possible as implementation of the NAS Plan progresses. All of these projects could be completed near the turn of the century.

The third category of projects, New Initiatives, consists of projects that will apply new or emerging technologies and permit the application of these advances as rapidly as possible.

The fourth category, Sustaining R,E&D Activities, is a group of projects that will continue over long time periods in support of aviation security, improved equipment, new standards for airports, and aircraft safety. Also included are research for the certification of new aircraft, avionics, and pilots; advances in aviation medicine; and environmental considerations.

The fifth category, System Studies, is an ongoing activity aimed at developing and regularly updating the R,E&D Plan. This category also includes the identification of advanced concepts for providing improvements in air traffic services in the far term.

4.3
Direct Support of the NAS Plan

Thirteen NAS Plan projects are supported by the R,E&D Plan, as follows:

Traffic Management System—to enhance ATC system capabilities for monitoring and balancing demand to available capacity, and to provide users with improved flight planning information. New functions will include departure flow metering, automated airport capacity calculations, improved system performance measures and graphic displays, runway configuration management tools, and automated traffic flow resolution alternatives.

Flight Service Automation System Enhancements—to improve the delivery of flight-critical and flight-planning information to users. Graphics and weather radar data will be added to assist the flight specialists. Means of direct user access will be provided, ranging from a voice response system to voice and data link of weather and direct user access terminals.

Advanced Automation System—to replace the existing en route automation hardware and software. Terminal and en route automation functions will be combined in Area Control Facilities (ACFs). New controller workstations will improve the human interface with the automation system. Automation enhancements will provide controllers with new tools for handling increased traffic demand.

Automated En Route ATC—to provide new software with capabilities to plan and monitor the flow of air traffic. These capabilities include flight plan probes and sector workload predictions; they will support direct routing of aircraft, providing routes free of conflicts with other aircraft, special use airspace, or traffic flow restrictions. At the same time, system safety will be improved as a result of the lower potential for operational errors, and controller productivity will be increased.

Voice Switching and Control System—to perform the intercom, interphone, and air-ground voice connectivity and control functions needed for ATC operations in an ACF.

National Airspace Data Interchange Network (NADIN) II—to enhance NADIN to meet the data transfer requirements of evolving FAA facilities. System enhancements will provide additional capacity, connectivity, and interfaces.

Precision Approach and Landing—to develop operational procedures and criteria making use of the Microwave Landing System's wide-angle coverage in precision approach and landing operations. Standards for implementation will be developed, as will advanced configurations of ground and avionics equipment.

Weather Sensor Development—to evaluate automated weather observing systems; conduct research on low-altitude wind shear detection systems and the effects of wind shear on aircraft operation; and evaluate other advanced weather sensors.

Advanced Weather Radars—to develop a new generation of Doppler weather radars that will provide improved information on precipitation, reflectively, wind velocity, and turbulence. Development efforts will address both en route and terminal airspace applications.

Weather Processing—to develop a Central Weather Processor that will process and disseminate real-time weather information throughout the NAS, and will improve information and short-range forecasts provided to aircraft operators, flight specialists, and controllers.

Low-Level Wind Shear Alert System Enhancements—to improve the ability to detect wind shear with reduced false alarms and improved interpretation. This project also includes enhancements that involve the development of operational procedures for controller and pilot use upon detection of a wind shear event.

Utilization of the Global Positioning System (GPS) for Civil Air Navigation—to develop an integrity monitor for GPS. In subsequent enhancements, procedures and standards for the use of GPS for civil air navigation will also be developed.

Traffic Alert and Collision Avoidance System—to develop a ground-independent airborne collision avoidance capability, and standards and certification guidance to support implementation of this capability.

4.4
NAS Enhancements and New Initiatives

The NAS Plan provides a basis for further enhancements to provide new capabilities and improved efficiencies. The NAS Enhancements projects focus on the development of new operational procedures, extensions of NAS hardware and software functions, and the development of more accurate and accessible data bases. Looking ahead to the year 2000 and beyond, New Initiatives projects would pursue improvements that will depend on advances in technology in the fields of ATC procedures, computers, communications, and satellite-based services. The discussion below characterizes NAS Enhancements and New Initiatives from a functional perspective.

4.4.1
Capacity Improvements

A number of projects address the problem of increasing airport and airspace capacity to meet growing demand and reduce delays imposed on users. The principal efforts planned to improve capacity are:

Improved use of runway configurations, both existing and new—Improved communications, navigation, and surveillance (CNS) services would support reduced vehicle separations during approach and the development of new flexible approach procedures. Such procedures could alleviate conflicting approach and departure traffic patterns among adjacent runways and airports. Improved CNS services could support the independent operation of closely spaced parallel runways, as well as converging Instrument Flight Rules (IFR) approaches.

New runway configurations would be developed, such as independent short runways for Vertical Take-Off and Landing (VTOL), Short Take-Off and Landing (STOL), and general aviation aircraft. Precision approach guidance would support the use of these approaches within busy terminal environments. Runway configuration management would be implemented to advise controllers of optimal airport runway configurations, given arrival traffic characteristics, weather conditions, and airport facilities status.

Other initiatives designed to support reduced vehicle separation address the avoidance of hazardous wake vortices. Improvements in forecasting and studies of aircraft performance can lead to separations adapted to the actual duration of the hazard.

Traffic management improvements—These improvements would better match traffic demand to available capacity. Traffic management and metering features would adapt aircraft arrival rates to terminal acceptance rates. Departure traffic management features would provide the interface with metering automation so that departures would be released at times consistent with the acceptance rates of the destination airports.

Integrated control of major terminal airspace comprising several major and reliever airports (e.g., specified airports in New York or in the Los Angeles Basin)—New initiatives designed to increase the flexibility of using reliever airports would exploit automation improvements. Operational and procedural enhancements would utilize advances in technology with the goal of increasing terminal area capacity.

Use of time-based ATC techniques to further improve terminal area capacity—By permitting more precise control of traffic than is currently obtained using speed control and vectors, reduced interarrival dispersion of aircraft would improve the use of available runway capacity. Aircraft equipped for four-dimensional (4D) navigation would receive 4D clearances to the runway threshold. Aircraft in the terminal area without a 4D navigation capability but equipped with Mode S would receive pseudo-4D clearances in the form of speed objectives and vectors (headings and altitudes) from the automation system via Mode S data link. The challenge for the R,E&D project will be to use the new parameter of time in a way that will make these new procedures feasible, i.e., without detrimental effects on capacity. The challenge in incorporating time-based ATC concepts in the terminal environment is to accommodate the general disparity in aircraft and avionics capabilities and in pilot skill levels. Time-based ATC practices in this environment may require the segregation of aircraft by capabilities, with 4D-capable aircraft assigned to specific runways.

Airport Surface Traffic Automation—This capability would be developed to assist tower controllers in safely and efficiently routing aircraft and other ground vehicles between gates and runways and elsewhere on the airport surface. Airport surface detection equipment and algorithms would monitor runways, exits, taxiways, and gates so that efficient traffic movement may be maintained, even in conditions of reduced visibility.

Improved weather services—This effort would support capacity increases and delay reduction through improvements in forecasting and the distribution of weather data. Timely and accurate knowledge of winds aloft and storm activity would be needed to support the traffic management improvements and time-based navigation described above. Improved detection of and response to wind shear events can support the best use of available capacity under these conditions. Unanticipated storm events can lead to delays for many users; improved forecasting and distribution of weather data would make it possible for many delays to be avoided, and others to be taken on the ground or at high altitudes.

Special use airspace (such as restricted airspace or military operations areas)—Such airspace would be allocated and released as required. This dynamic airspace management would be interfaced with national and local traffic management functions, making the affected airspace available to civil aviation whenever possible.

Oceanic airspace—Improved oceanic ATC systems would be developed that will utilize extended CNS coverage. Minimum permissible vehicle separation may be reduced, providing more capacity on the oceanic tracks preferred by users.

4.4.2 Flexible Routing Initiatives

User productivity is closely related to the extent to which the NAS can accommodate flexible routes. The availability of flexible routes means that the user can select the route of flight. Currently, altitude and speed may be constrained by ATC requirements; with user-preferred trajectories, the user would select routes, vertical profiles, and speeds. The NAS Plan includes a number of features designed to facilitate flexible routes in the en route environment. These features will probe the airspace ahead of aircraft for potential conflicts and provide fuel-efficient clearances for deviations required to resolve such conflicts. Initiatives beyond these NAS Plan features are intended to extend these features in a number of important ways, as described below.

The NAS Plan probes—would accommodate user-preferred trajectories by taking into account the pre-planned aircraft altitude and speed selected by the aircraft flight management system. These probes would check for conflict-free paths, ensuring separation from other aircraft, but otherwise allowing maximum use of airspace. In the event of unforeseen conflicts, automated resolution aids would suggest several choices of resolution strategy, rank ordered so as to best accommodate aircraft intentions while solving the problem. Ultimately, with transmission of waypoints from flight management computers via a data link, an automated ATC system would become more capable of honoring individual aircraft intentions. The automation functions would accomplish this task reliably and without the impact on workload that would result in the present system.

Traffic management features—would be developed for efficiently using available airport and airspace resources to accommodate user-preferred trajectories. The traffic management process would check flight plan requests against anticipated demand. Clearances would then be issued, or flight plans would be revised if necessitated by foreseen congestion or traffic flow restrictions. Traffic management would be capable of adapting to special use airspace as it is activated and released; this dynamic process would make the best use of airspace when it is available, and still honor restrictions whenever required.

The traffic management function ultimately would be integrated with the flight management function of ATC into a flow management system. Both functions would utilize the same data, and would operate in a fully coordinated manner.

The use of time-based ATC practices in the en route environment—would involve issuing 4D clearances to aircraft, that is, clearances to arrive at points in space at specified times. Aircraft equipped with flight management systems are able to satisfy such clearances automatically along fuel-efficient trajectories. In order for aircraft not equipped with flight management systems to meet such clearances, speeds and vectors would need to be provided to the pilot. It is envisioned that ground-air data link would be used to provide both the 4D and the pseudo-4D clearances to the cockpit.

Time-based ATC practices provide a means by which ground automation equipment can communicate directly with flight management systems in aircraft to provide automatic fuel-efficient clearances without necessary intervention by either pilots or controllers. While substantial R,E&D effort is required to fully understand the technical and operational implications of such practices, they are clearly appealing, from the standpoint of both efficiency of aircraft operations and productivity of ground ATC operations.

Terminal ATC automation—would provide the automated tools needed for controlling aircraft arriving on flexible approach and departure paths. These tools would include automated sequencing and scheduling, speed

control, vectoring, and time-based clearances. Arrival and departure routes could be adapted to demand and to the active runway configurations, with arrival routes assigned to aircraft before they entered the terminal area. Automation would support control capabilities involving innovative access and egress strategies that might impose too heavy a burden with today's ATC operations.

Extensions of CNS services—would extend ATC service to more airspace in support of flexible routes. This airspace includes extreme (low and high) altitudes, oceanic, offshore, remote, and urban environments. The automated probes and traffic management features described above would be extended to new airspace, as well as to new users who might wish to receive these services.

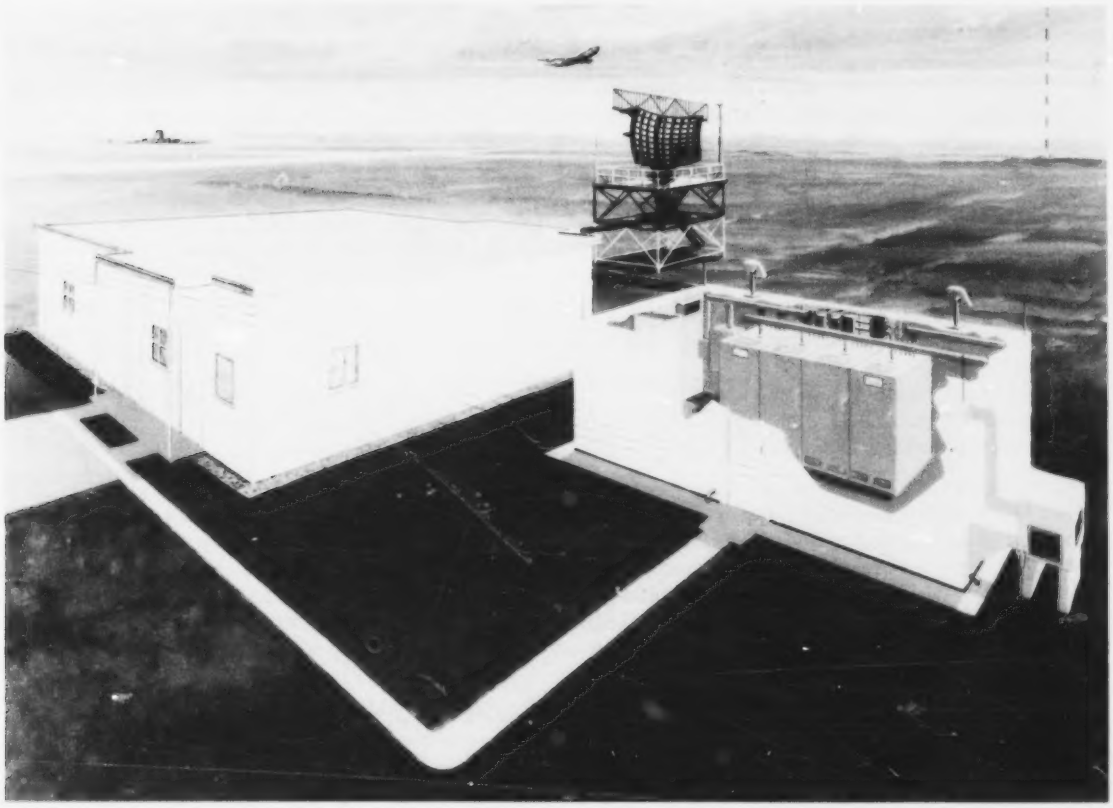
Improved weather and flight planning information—would help users avoid unexpected diversions or delays due to weather conditions or traffic flow restrictions. In-flight distribution of these data would enable users to select their preferred course of action.

4.4.3 CNS Extensions

CNS services would be extended to additional airspace to meet user operational requirements. In addition, new capabilities would be made available to users.

Communications extensions would initially enhance the capabilities of FAA facilities to support the shared data bases and automated functions described earlier. In concert with the increasing demand for services, a modern

network management and control system must be implemented. To provide real-time access to data, digital data link applications will be developed for transmitting weather data, airspace restrictions, delay information, and ATC clearances to aircraft. The data link will also enable aircraft to transmit winds aloft, flight intentions, and position reports to ATC. In the near term, Mode S ground stations will provide the data link. Later, satellite data link may be implemented, extending coverage to oceanic airspace and extreme (low and high) altitudes. In addition, other technical means would be explored for providing communications services to rotorcraft operating in low-altitude, offshore, or urban environments, as well as telecommunications on the airport surface. Both of these applications involve user operations outside the coverage of Mode S ground stations, requiring service in advance of the introduction of satellite-based data link.



Navigation extensions would initially improve the utility and performance of existing navigation systems. Alternative concepts would address service for oceanic and remote areas. Performance standards would be developed for using area navigation equipment for direct routing. A key initiative would explore use of the GPS in civil aviation as a sole means of navigation, and its application for nonprecision instrument approach.

Surveillance extensions to new airspace are envisioned by means of automatic dependent surveillance (ADS) techniques. With ADS, an aircraft uses onboard navigation equipment to determine its position, and automatically transmits this information to ground-based ATC. ADS can be based on a variety of means for

navigation. In an oceanic environment, inertial navigation systems (INS) and GPS are the most likely means; in low-altitude/offshore/remote area airspace, vehicles could use these systems or existing navigation equipment, such as Loran C. For ADS communications, the application of dedicated satellites will be considered, as will existing technologies and systems, such as high frequency (HF), and commercial satellite data link. The real-time ADS surveillance data can be used for controlling aircraft separations in airspace where ground-based radar is not feasible (oceanic, low-altitude, and remote areas), or as a supplement to primary radar. Such real-time surveillance could improve the safety of flight operations while increasing airspace capacity by supporting reduced minimum permissible vehicle separation. In the oceanic environment, this enhancement could be combined with automation and procedural initiatives described below to reduce fuel consumption by permitting shifts in tracks to account for changes in winds aloft. The initial phase of this effort will investigate the use of current avionics, using the Oceanic Display and Planning System as a baseline for controller display; subsequent phases will focus on developing improved avionics and integrating ADS with controller displays.

Other surveillance extensions include improvements in ground-based sensor accuracy and resolution, and the provision of low-altitude and surface surveillance.

4.4.4 Weather Service Extensions

Improvements to aviation weather services address three principal areas:

- Observation of weather
- Analysis of observation data and the generation of products for users
- Distribution and dissemination of weather products

The weather program involves the entire range of airspace users. Many of the system development efforts and the weather service elements within this program will involve cooperation with other government agencies. The highlights of these service improvements are:

Observation—A number of efforts address the frequency of observation, and the accuracy as well as temporal and spatial resolution of weather data. The automation of surface weather observations is being undertaken in a joint program. The system under development will measure wind direction and speed, temperature, atmospheric pressure, precipitation, visibility, and cloud height. Improvements are planned for the measurement of cloud height and the identification of precipitation. The acquisition of upper air data will evolve from balloon soundings to ground-based tropospheric microwave radar, and later to satellite-based infrared radiometric sounders. Atmospheric measurements taken by aircraft will also be incorporated, using data link communications.

A Next Generation Weather Radar is being developed in another joint program. This radar is intended to improve the timely detection of hazardous weather phenomena by detecting the location of gust fronts, hurricanes, and turbulence. Development of a separate Terminal Doppler Weather Radar, which will detect wind shear and other hazardous weather in the immediate vicinity of an airport, has also been initiated. This system will provide real-time information and support improved short-term forecasts of terminal area conditions. Research will continue toward improving the detection of wind shear and other hazardous events.

Data processing—While weather analysis and forecasting are primarily the responsibility of the National Weather Service, the FAA is developing forecasting techniques tailored to the needs of its users. These include computer-generated short-term forecasts and route-oriented forecasts. The FAA is participating in a national long-range research program for improving near real-time forecasts for operational applications.

Efforts are planned for the development of a centralized data base of all weather products, and automated means of input and output of information. When fully automated, the system will generate routine and hazardous weather information for each pilot-defined route.

Information distribution—The third area of weather service improvements involves the distribution of information to each user at the proper time. Efforts to improve data handling and distribution include the Central Weather Processor, Aviation Weather Processor, Weather Communications Processor, Mode S Data Link, National Airspace Data Interchange Network, National Interfacility Communications System, and the Weather Message Switching Center Replacement. These and subsequent developments will permit access to needed data. The development of data link applications will improve access to these data from the cockpit.

4.4.5
Flight Planning Service Extensions

The R,E&D Plan includes improvements to flight planning functions. These will benefit user efficiency and support many of the overall system efficiency improvements described above. The two principal areas addressed are the establishment of improved data bases and the distribution of data.

The efforts directed toward data bases address weather, airspace restrictions, traffic delays, and facility and airport status. Weather improvements, as described earlier, will provide route-directed forecasts using current information. Improved observations and forecasts of clouds, winds, temperatures, and storm activity will be made available. The use of aircraft-measured data and the rapid availability of these data in the data base will improve the timeliness of this aspect of flight planning. The user will also access current information on airspace restrictions, including planned times of activation and release of special use airspace. Data on traffic delays and congestion will be made available in a timely manner to support advance planning that will permit the selection of alternate routes or the taking of delays in a preferred manner. The current status of NAS facilities, such as navigation aids, and of airports, such as closed runways or degraded surface conditions, will also be available in the data base.

Flight planning data would be distributed to users in several ways. Preflight data will be accessible to flight specialists, to aircrews using direct access or self-briefing voice response terminals, or directly by computer data link. Preflight planning would later include user requests for preferred trajectories and the corresponding clearances from ATC.

The same data would also be made available in flight. Data link would expedite requests for information and its distribution. This capability would be provided initially by Mode S, but later might be provided using satellites, to extend coverage to oceanic airspace, low altitudes, and urban areas. Routine and hazardous weather would be transmitted initially via VHF Omnidirectional Ranges (VORs), and later via data link. Data link would be used to respond to in-flight requests for weather data and for revised clearances.

4.5
Sustaining R,E&D Activities

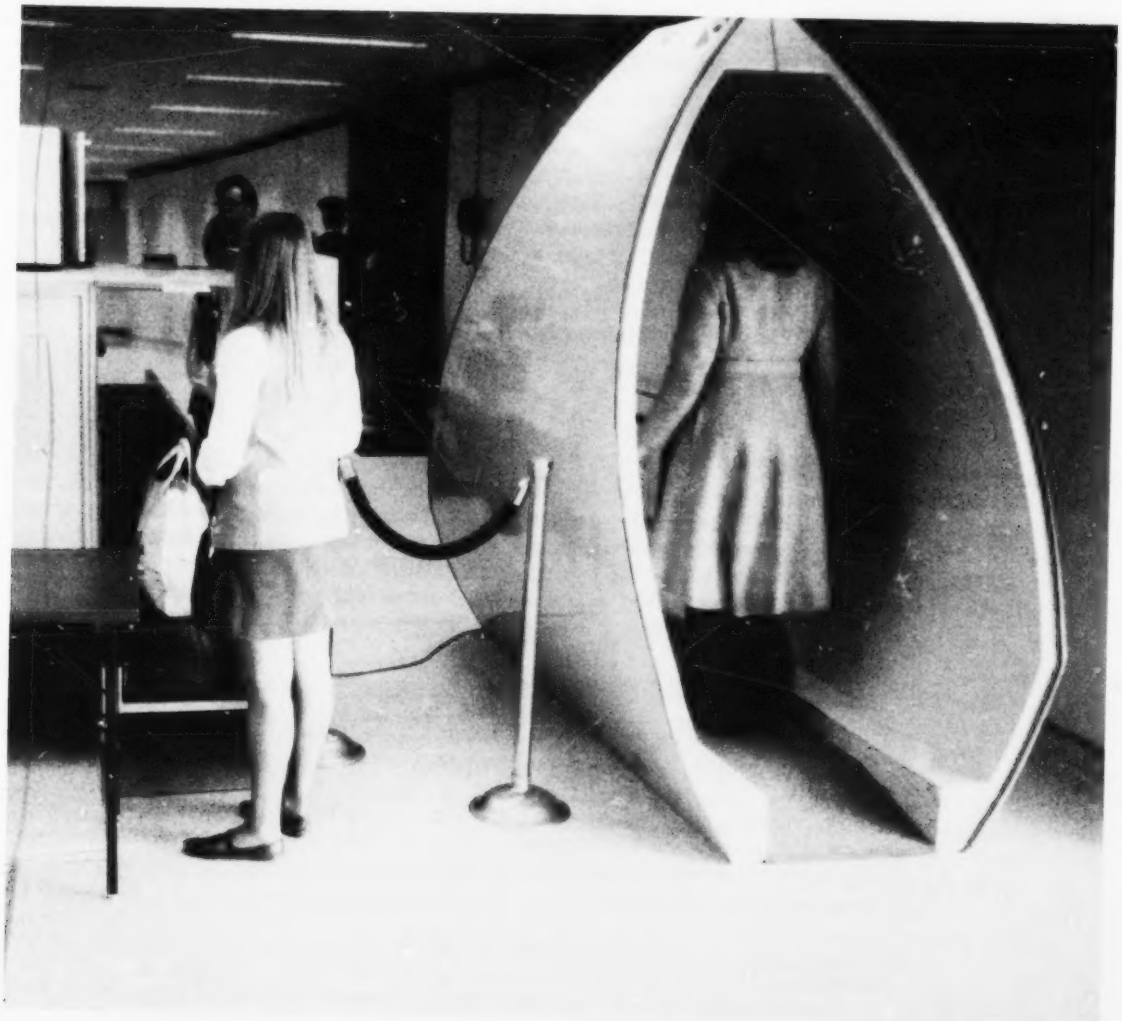
Certain areas important to the FAA's mission require ongoing R,E&D for continuing improvement. Principal development efforts in these areas address the following:

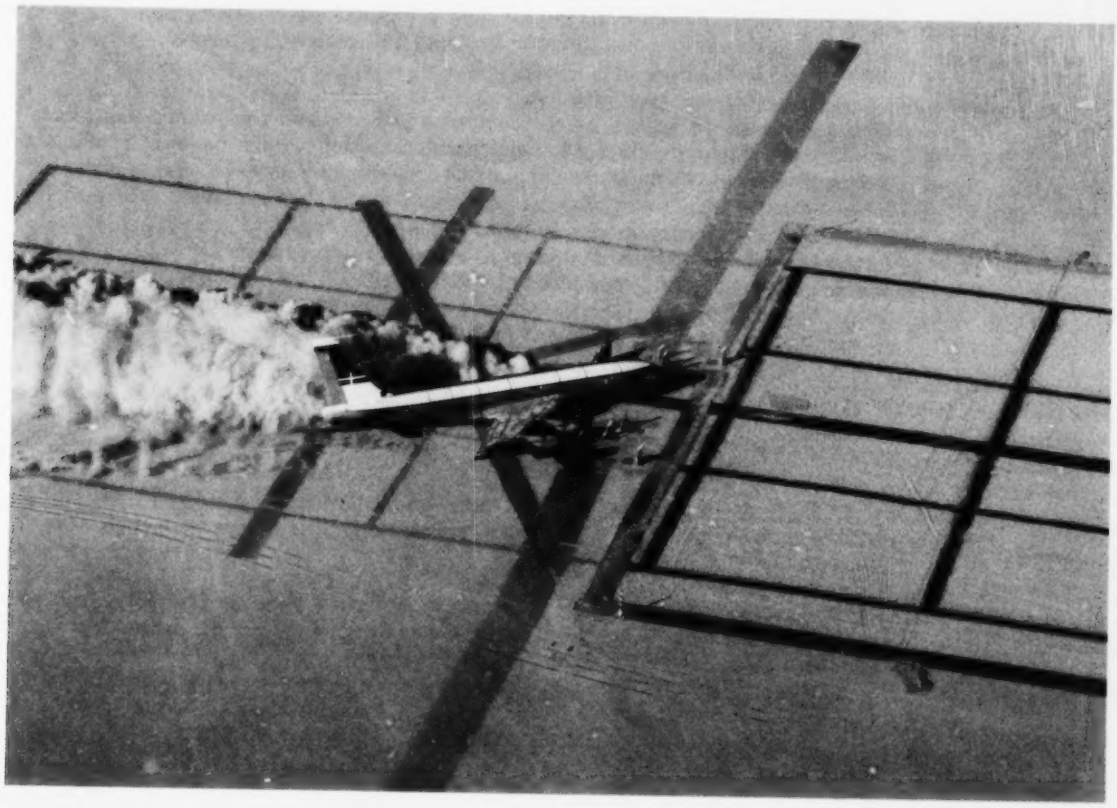
Aviation security—to develop improved methods of meeting the threat of hijacking and terrorism. Improved procedures and equipment will provide protection at many points. Projects in this area address the detection of concealed weapons and explosives through improved technology and more efficient screening of passengers, checked baggage, and cargo.

Aircraft safety—to improve passenger and aircraft safety in flight and in the post-crash environment. In-flight safety improvements address airworthiness criteria for aircraft structures and propulsion systems; assessment of atmospheric and electrical hazards; icing hazards; and the development of guidelines for certification and maintenance of onboard computer hardware and software. Efforts in the crashworthiness area address flammability and toxicity criteria for materials, the detection and control of fires, the performance of seat structures and passenger restraints, and emergency procedures.

Aviation medicine—to improve the safety of civil aviation and the health, safety, and efficiency of agency employees. R,E&D efforts address human performance factors to improve the safety and efficiency of ATC and of aircraft cockpit operations, and to reduce fatigue, illness, use of drugs, and other job stresses. Other projects address the medical aspects of protection and survival following accidents, and the health of airmen.

Airports—to provide standards and guidelines for the design, construction, operation, and maintenance of airports. These encompass pavement construction; runway, taxiway, apron, and gate configurations; heliports; fire and rescue methods; snow and ice control; airport surface lighting and visual aids; bird and wildlife control; and runway surface contamination. These developments are expected to evolve to accommodate new aircraft types and modes of operation.





4.6
System Studies

The System Studies category consists of two projects designed to support R,E&D program planning. The first project, NAS Development Studies, will progress from requirements analysis to the identification of technological and operational alternatives for meeting the requirements, and the analysis and selection of candidate approaches for development. The principal product of this project is the annual R,E&D Plan. Consultation with the aviation community will provide a means of incorporating user concerns. The second project, Advanced Concepts Studies, will explore advanced technologies and concepts for future application.

4.6.1
NAS Development Studies

The NAS Development Studies project is designed to identify future new initiatives through the systematic analysis outlined below:

Performance assessment of the NAS to identify areas in which future R,E&D needs may arise.

Demand analysis, to include anticipated growth, increased range of vehicle types, and requirements for supporting a greater variety of flight operations.

Requirements definition, which will translate system-level needs into specific, quantitative problems for consideration by the R,E&D projects.

Assessment of NAS development plans, to determine the extent to which existing plans anticipate the requirements developed under the preceding step, and to identify requirements that must be addressed by further R,E&D efforts.

Technological and operational assessment of development alternatives, aimed at analyzing the capabilities of candidate alternatives to meet new requirements. This step requires both a comprehensive definition of the technical means of meeting these requirements and the development of operational concepts for implementing NAS enhancements.

Cost-benefit analysis to determine whether technically and operationally viable alternatives can meet requirements at acceptable cost levels.

Assessment of the anticipated impacts of proposed NAS evolution, completing the development of an evolutionary plan that incorporates future enhancements within the NAS.

Annual publication of the R,E&D Plan, which describes the development work required to ensure the intended long-term NAS evolution. This plan organizes the development work into specific projects with defined products, activities, and schedules.

4.6.2 Advanced Concepts Studies

This project will develop concepts and applications beyond those currently identified. These applications will not necessarily be requirements-driven, as in the preceding project, but instead will involve exploring emerging technological breakthroughs or innovative operational concepts. In these studies, concepts may begin with a "clean sheet of paper," as opposed to the conventional approach in which plans represent an evolution from existing equipment and procedures. After concept feasibility studies have been performed, those concepts that merit further development will generate further New Initiatives projects.

Chapter 5
A View of the NAS in 2010

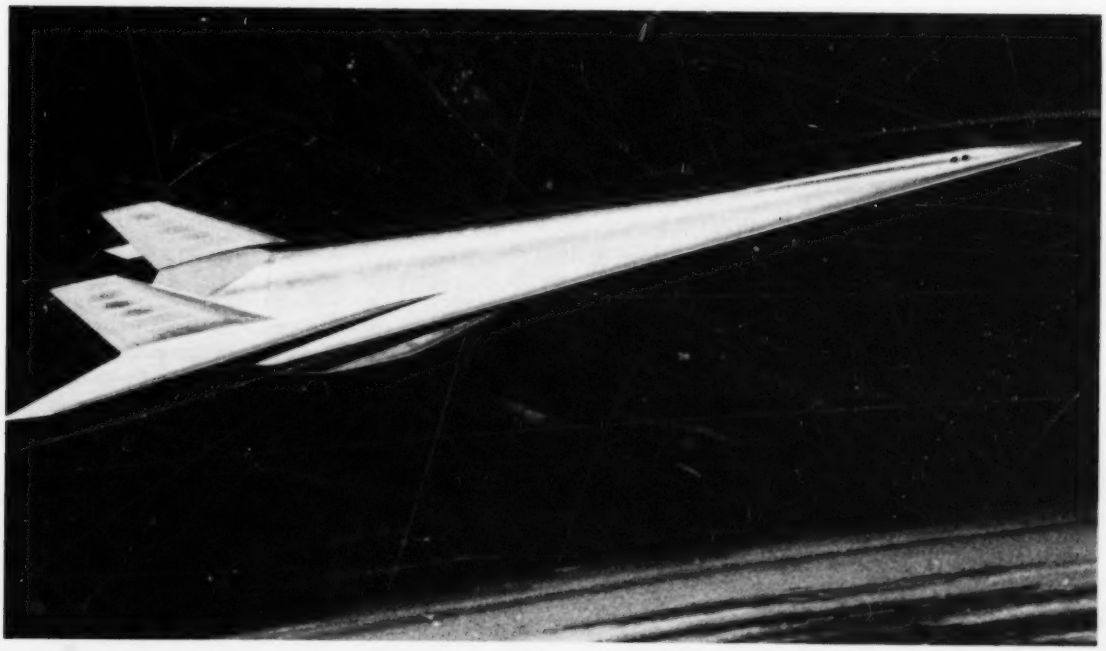
The far-term goal is a highly efficient system combining the results of many development efforts.

By the year 2010, the R,E&D Plan envisions that NAS requirements for capacity, productivity, accommodation of diverse vehicle types and operations, safety, environmental conservation, and freedom of the airspace will be met through the application of technology and associated improved practices and procedures. Improvements in automation, together with those in airports, surveillance, landing systems, data link communications, and weather services, will play a central role in increasing capacity, productivity, and safety. In addition, the application of satellites to communications, navigation, and surveillance (CNS) is expected. Satellites offer the potential for increasing the coverage of these services to low altitudes, offshore regions, remote areas, and oceanic environments. Moreover, in the long run, they may provide a significant potential for reducing the number of different avionics packages carried aboard an aircraft for CNS services. In addition, new standards and guidelines will be developed for airports, crashworthiness and airworthiness of aircraft, and flammability and toxicity of materials. Biomedical and human behavioral aspects will be examined continually in an effort to reduce human errors in the system. Finally, persons and property within the NAS will be provided with improved protection against acts of violence and aircraft piracy.

The fundamental NAS services have been described in Chapter 2. This chapter describes the advanced-technology aircraft that should be introduced by 2010, and describes the evolution goals for this time period for those services upon which the R,E&D Plan is based. Addressed in turn are flow management, flight planning and in-flight advisories, and CNS. In general, the improved services will be available to users who equip with the new systems; other users, who have no need for certain services, will not so equip. It should also be noted that the goals delineated in this chapter are subject to considerable change as the R,E&D activities proceed. This description is provided as a coherent view of development goals; it is not intended to suggest that alternatives are precluded.

5.1
Advanced-Technology Aircraft

The NAS R,E&D Plan looks forward to the introduction of improved subsonic, supersonic, and even hypersonic (transatmospheric) aircraft. A principal objective in the development of these aircraft is high-speed, fuel-efficient air transportation. This objective can be achieved only if the NAS is prepared to support these operations.



A principal R,E&D initiative that would support these aircraft is the concept of time-based ATC, whereby ground automation equipment would automatically provide conflict-free 4D clearances to flight management systems to ensure fuel-efficient operation. Initially, these concepts would be introduced in the homogeneous high-altitude en route airspace; they would be extended later to the terminal environment.

Civil and military aircraft would operate over an increased range of altitudes—up to 70,000 feet for supersonic transport aircraft, and 100,000 feet for hypersonic transport vehicles. These aircraft would have sophisticated flight management systems on board that would facilitate generating and following fuel-efficient paths with flexible vertical profiles. This capability would require a direct interface of airborne and ATC ground computers by data link, accurate reporting and forecasting of winds aloft and severe hazardous weather, and a nearly automatic ATC system that can generate appropriate clearances for the fuel-efficient paths and profiles generated by the airborne flight management systems. The controller's job in this time period would become that of a manager who would intervene only for resolving potential emergency situations. Although initial implementation is seen as occurring in very high altitudes, the service would be progressively extended to aircraft operating at lower altitudes as system performance was proven and airborne equipage permitted.

Two additional initiatives would support the introduction of these new vehicles. The first is the development of appropriate standards for airports and associated facilities. The second is an initiative designed to expedite the development of aircraft certification guidance in parallel with technology developments. The objective here is to ensure that technology can be applied when it is mature with a minimum amount of additional delay for generating certification criteria.

5.2
Flow Management

ATC in the year 2010 is envisioned as a highly automated, ground-based flow management system integrating the ATC functions of traffic management and flight management. The flow management system would process user flight plan requests, considering weather and winds, both current and forecast. The availability of NAS resources would also be considered, enabling conflict-free clearances to be issued to users according to their capabilities: either in 4D, pseudo-4D, or conventional form. The same system would provide the tactical flight management ATC function, utilizing its knowledge of clearances and aircraft intent in resolving any conflicts between aircraft or due to airspace restrictions.

Such a flow management system would provide better assurance that users could fly the flight paths they prefer without diversions due to unanticipated weather events or airspace congestion. Ideally, a user would be able to request a preferred trajectory (i.e., a route of flight with associated altitude and speed profiles) and a preferred departure time. Weather and traffic permitting, the flight path would be cleared, and once airborne, the aircraft would not be rerouted. The degree to which route changes would be required would result from the extent and accuracy of the weather, traffic, airspace, and capacity predictions.

By the year 2010, the system would accommodate user-preferred trajectories (i.e., speed profile and cruise climb). Using improved winds aloft and weather front predictions, as well as improved demand and capacity estimates, improved algorithms would be available so that user-preferred trajectories could be accepted routinely, and individual flights could thereby operate with minimum constraints and maximum efficiency. The system would process flight plan requests and communicate with the user through the flight planning process to adjust the departure time or flight trajectory. After the flight plan is accepted by the user, flow management would ensure that, in the absence of an unforeseen change in capacity, the flight could be cleared to land with little likelihood of delays or restrictions. The evolution of the traffic management function in the oceanic airspace would parallel that expected in the domestic airspace.

The automation algorithms that would support user-preferred trajectories would contain the following functions:

Conflict Probe, using the best available intent data (i.e., flight plans, clearances, flight path intent data from the aircraft's flight management system, and wind and weather forecasts) to determine if a flight profile is clear of other traffic, special use airspace, and terrain. The time horizon would be on the order of 30 minutes.

Conflict Alert, notifying the controller that projected profiles are predicted to violate separation standards or come too close to restricted airspace and terrain.

Conflict Resolution, providing alternative strategies for resolving a projected conflict.

Improvements to separation services in en route airspace will be a direct result of the automation tools described in the NAS Plan. By the year 2010, the ATC computer would generate the control commands and automatically notify the aircraft via data link.

The Advanced Automation System (AAS) would provide the required computer system capacity, reliability, and availability. The AAS algorithms for conflict probes and separation monitoring would use flight path intent data transmitted via data link from the aircraft's flight management system, as well as more accurate, current, and predicted winds aloft data, and would incorporate time-based resolution advisories. Procedures and supporting automation will facilitate the accommodation of user-preferred trajectories and permit the routine granting of flexible routes.

The automation algorithms would also accept next-generation aircraft operating at very high speeds—Mach 3 for supersonic transports and as high as Mach 12 for hypersonic transports. These algorithms would account for the transition to airspace in which the aircraft continue to operate at speeds typical of those used today. Aircraft would be able to fly preferred trajectories in most controlled airspace, with ground computers providing the clearances and resolution advisories, and the Traffic Alert and Collision Avoidance System (TCAS) providing a backup capability. Separation services would also be provided in low-altitude, offshore, and remote areas, based on automatic real-time position reports. ATC separation services will be provided to rotorcraft and will be integrated with the AAS to accommodate user-preferred trajectories.

Terminal ATC automation would provide approach controllers with arrival sequence planning information. This information would include recommended runway configurations that would maximize airport capacity based on current and predicted weather and winds aloft, traffic demand, and airport facilities and equipment status. Terminal automation would aid en route arrival sector and approach controllers in assigning aircraft to a runway at airports with multiple arrival runways, to minimize unnecessary delay. The automation aids would also recommend to controllers separation-assured clearances that would meet the planned arrival sequence with minimum allowable spacing between aircraft, thus maximizing arrival throughput. These computer-generated clearances would be automatically data linked to appropriately equipped aircraft.

Airport Surface Detection Equipment (ASDE) capabilities would be augmented to provide automatic radar tracking and target classification. Data link would be integrated to provide aircraft identification. Automated control of ground traffic at airport runway/taxiway intersections would be developed, and would use ground surveillance data. Data link could provide runway-to-gate clearances automatically to appropriately equipped aircraft.

Oceanic automation would perform functions analogous to those of en route automation. The AAS would provide controllers with a current situation display based on flight plans and automatic dependent surveillance (ADS) position reports, and with a flight plan probe that would permit near-real-time separation monitoring. In addition, it is envisioned that horizontal and vertical separation would be reduced in oceanic airspace, leading to increased track flexibility and capacity.

5.3
Flight Planning and In-Flight Advisories

Improvements in flight planning information would be reflected in the content, accuracy, and timeliness of aeronautical and weather briefing information. Significant improvements in severe weather detection and forecasting, through satellites and airborne sensors, would lead to fewer operational disruptions in the vicinity of severe weather. In addition, improved wind data, both current and forecast, would be provided for use by ground and airborne computers. Winds aloft data from suitably equipped aircraft would be transmitted via data link to ground computers for use in ATC automation in en route and terminal areas. Major advances in weather sensing and information dissemination would occur. A central weather processing facility would automatically distribute weather information. More complete weather information would be available with the use of automatic remote site weather sensing devices.

Flight plan filing would be accomplished by direct user access to up-to-the-minute flight planning data bases over commercially available communication systems. The flight planning computer would automatically identify constraints, and permit users to request flight plans based on the constraints relevant to their flights. The use of automation would permit the effective utilization of FAA resources, and would provide users with timely access to information needed to simplify the flight planning and filing process. This simplification may in turn encourage more general aviation users to file flight plans.

In-flight access to flight plan services would be provided using the Mode S data link. Data link access would also be extended to oceanic and low-altitude airspace.

5.4
CNS

Air-ground communications would continue to be the primary vehicle used by the pilot and controller in making and processing requests for in-flight services and flight paths; these communications would improve with the use of data link and satellites. The Mode S data link would continue to provide the coupling with ground automation. In addition, satellites would be employed to extend air-ground voice and data communications to low-altitude and remote areas, and to oceanic airspace.

The data link services provided would include automatic hazardous weather information; confirmation of assigned altitude, and special use airspace advisories; real-time flight plan processing; and information on aircraft position and flight path intent.

Should voice communication be necessary, the channel used would be assigned by the computer without any controller or pilot intervention. Mission-oriented data communication would be provided in all phases of flight operations—from gate departure to en route flight to gate arrival. Essential information would be provided on both request-reply and automated bases, thus making full use of automation while at the same time reducing workload. Satellites would be used to provide data link services to low-altitude and remote areas and to oceanic airspace.

With a combination of Mode S, satellite, and HF data links, an expansive communications architecture would integrate the various data links. Additional data link services would be provided to meet growing user needs. Voice capability would be added to satellite services so that users could get voice and data in the same avionics package.

Improvements in navigation and landing would integrate the various area navigation systems into the NAS by developing a reference system for describing fixes and intersections compatible with vectors that might be issued by ATC. These improvements would also exploit satellite technology so that it could support nonprecision approaches to most runways. Included as well would be the development of procedures for effectively using the multiple path capability of the Microwave Landing System (MLS).

Navigation system improvements would extend en route navigation service to low-altitude and remote areas and oceanic airspace, and would also extend landing services to more runways and along more final approach paths. The en route navigation service would utilize the Global Positioning Satellite (GPS) system. GPS would readily support user-defined "direct routes" and "area of operation" flights, and would also support nonprecision approaches to runways currently not served by the precision landing system. Landing, missed approach, and take-off guidance would be provided by the MLS. The increased accuracy and path flexibility provided by this system would support the operation of closely spaced parallel runways, converging approaches, and precision guidance to secondary runways so that airport capacity could be increased.

While VHF Omnidirectional Range (VOR) would continue to support operations for many general aviation aircraft, a transition to a satellite system (GPS) would have been accomplished for many other users. GPS would support helicopter operations at low altitudes and in transoceanic operations, and would provide instrument approaches to more runways. Thus in high-density terminal areas, runways at secondary airports would be used to ease the capacity situation. The precision landing system would provide service to lower minima, including all-weather landing service; guidance along the airport surface would also be provided in all-weather conditions.

Surveillance would continue to support the radar separation standards used throughout the NAS. This service would benefit from the improved accuracy of the various radars, integrated data from several radars, Mode S, improved surveillance coverage on the airport surface, extended surveillance coverage into low-altitude and remote areas and oceanic airspace, and a landing monitor for closely spaced runway applications.

The improved sensor accuracy would provide better tracking performance for use by the automation system. To support operations for low-altitude and remote areas, alternative surveillance techniques would be utilized, including a low-cost Mode S and ADS (i.e., surveillance based on position reports); a low-altitude surveillance capability would be used for certain locations (e.g., downtown New York City). The availability of surveillance service into low-altitude and remote areas and oceanic airspace would support the use of radar-like separation standards for rotorcraft and fixed-wing operators, respectively, thereby increasing airspace capacity for these users.

Automation on the airport surface would provide efficient operation from runways to gates. The sequencing and routing of aircraft would be supported by ground automation aids using surveillance data. Aircraft surface guidance and control would utilize the available CNS services, including surface or satellite surveillance and communications, as well as suitable cockpit displays.

5.5
Benefits to the User Community

The vision of the NAS in 2010 shows improvements benefiting every segment of the user community. This section summarizes the major advances foreseen; it should be noted, of course, that each enhancement can benefit users other than those listed here.

Air Carriers—The NAS would provide the flexibility to support the mixture of conventional and improved subsonic, supersonic, and hypersonic aircraft in the fleet. Services would be extended to high altitudes, and ATC would accommodate transatmospheric operations. Users would be able to file flight plans for flexible routes using highly fuel-efficient trajectories. ATC would grant conflict-free clearances, and diversions would be rare. Improvements in airport capacity would allow these users to schedule operations at times of their choice. All-weather operations would maintain this peak capacity during IFR conditions, with a resultant avoidance of delays. Data link would provide real-time alerts for traffic delays and hazardous weather, and would facilitate requests for revised clearances.

Oceanic Users—Users of oceanic airspace would be granted clearances at, or near to, their desired routes and altitudes. Oceanic ATC would be automated, and would provide the flexibility to allow changes of track in flight, exploiting winds aloft data to improve fuel-efficient operations. Greater oceanic capacity would result from reduced separations, made possible by oceanic CNS services, primarily ADS. Oceanic ATC would probe routes for conflicts, and, using surveillance data, would simultaneously provide improved capacity and safety.

General Aviation—These users would receive CNS services throughout all airspace. This extended coverage would enhance safety and make ATC services available to those who might wish to use them. Satellite navigation service would enable direct routes to be flown. Satellites would provide nonprecision approach service at most airports. Flight planning assistance would include improved weather products and would be readily accessible, either directly from flight service specialists, by using terminals, or by data link. Data link would provide routine weather and hazardous weather warnings in flight; a limited voice capability would also be retained. A simplified set of avionics would provide these services. The principle of flexibility in the use of airspace would be maintained.

Rotorcraft—Users of rotorcraft would benefit from the extension of CNS services to the surface, and to remote, offshore, and urban environments. These users would gain additional flexibility and freedom of flight as their direct routing requests were accommodated by the system. Access to airports would be provided by new approach procedures based on features of an improved terminal automation system. These procedures would exploit precision guidance providing rotorcraft with separate approach paths to separate runways.

Appendix A
Rotorcraft Perspective of the NAS

A.1
Introduction

During the 1960s and 1970s, military developments were responsible for major helicopter improvements. Reliability was improved through the use of efficient turboshaft engines. Sophisticated stability and control augmentation systems helped to reduce crew workload and make instrument operations possible. The mass production of Army helicopters led to improved manufacturing techniques, helping to reduce costs. Moreover, the availability of former military helicopter pilots provided the civil sector with an ample supply of trained pilots. Comprehensive aeronautical technology forecasts produced by the Aeronautics and Space Engineering Board of the National Research Council clearly indicate a myriad of opportunities for quantum improvements in rotorcraft technology over the next 25 years. Current FAA plans include the preparation necessary to ensure that the NAS will maintain the cohesiveness and flexibility required to accommodate and keep pace with those future technologies.

Despite the higher operating cost of rotorcraft relative to fixed- wing aircraft, civil use has grown dramatically. Although operating costs have been steadily declining, rotorcraft costs are expected to continue to significantly exceed comparable airplane costs. By the same token, however, corresponding rotorcraft benefits are also large. As a result, rotorcraft were the fastest-growing segment of civil aviation in the early 1980s. By the year 2000, there are expected to be 10-15 thousand civil helicopters in the U.S.

The growth of civil helicopter usage during recent years can be categorized into two basic areas: special applications and passenger/property transport. Special applications include, for example, emergency medical service, law enforcement, fire fighting, logging, and construction. The number of special application users has grown steadily over the entire history of civil helicopter service. Although this growth will continue, the greatest future rotorcraft growth is expected to occur in the passenger transport arena. Helicopters are often referred to as *time machines* because their main benefit is realized in passenger time savings. Users of helicopters save enough time to more than offset the cost involved. On short-haul trips, helicopter usage reduces the need to change modes of transportation. Within an urban area, between city centers, or between remote and urban areas, helicopters are significantly faster than ground modes of transportation. Generally, they are used to go to places that are inaccessible by airplane; heliports require minimal real estate and can be constructed with relative ease.

Helicopter use for special applications has been possible without Instrument Flight Rules (IFR) capability, and IFR-equipped users have had limited opportunities to use such instrument capabilities. In spite of this, over half of today's helicopter deliveries are IFR-capable; moreover, passenger transportation demands the reliability of an IFR capability. Thus, the increasing need for passenger transportation by helicopter will result in a greater demand for IFR capabilities and will challenge the ATC system to provide for fuller use of these capabilities. The NAS was designed around airplanes and contains few explicit provisions for efficient helicopter operations. For example, in terminal areas, helicopters are often mixed with and vectored like airplanes, resulting in delays and additions to trip length and duration. The average helicopter flight today is 22 minutes. Delays and ATC vectors have a significant impact on fuel requirements.

In addition, low-altitude NAS services, such as communications, navigation, surveillance, ATC, and weather, are required. Direct routing, point-to-point IFR service is also essential; dog-legging from one VOR to the next is prohibitive because of the proportionately larger penalties incurred by short-haul users. Because helicopter landing and take-off operations are not limited to airports, NAS services are needed to support heliport operations in remote and downtown urban areas as well.

National policy decisions have been interpreted and included in the rotorcraft perspective of operations in the future NAS. "National Aeronautical R&D Goals—Technology for America's Future," issued by the White

House Office of Science and Technology Policy, places early emphasis on subsonic technology in building a sound foundation for transition to the 21st century, and to supersonic and transatmospheric technologies. It states as follows:

Accelerating subsonic technology can leverage unique advantages for the United States, by capitalizing on the pioneering efforts in airspace modernization and deregulation already in the national agenda. Significant national research and technology development is already in progress. However, key subsonic advances contributing to new transcending aircraft must be accelerated and readied by the mid-1990's to meet crucial competitive applications that will effect U.S. aeronautical momentum into the next century. It is essential for the National Airspace System Plan to maintain cohesiveness and flexibility to accommodate and keep pace with these future aircraft technologies. It is in this spirit that the future NAS will embrace helicopters and Vertical/Short Take-Off and Landing (V/STOL) aircraft, tapping the full potential benefit of this form of air transportation.

A.2
The FAA Rotorcraft Master Plan

The FAA Rotorcraft Master Plan outlines a comprehensive, coordinated effort to attain long-term goals that were jointly developed by the FAA and the rotorcraft industry. It defines the respective roles of the private and public sectors, and establishes requirements for FAA programs.

In response to the problems and needs discussed above, the Rotorcraft Master Plan defines three major thrusts:

To integrate rotorcraft into the NAS—This includes providing for the airspace planning, ATC procedures, weather, communications, navigation, surveillance, and flight operations planning and procedures needed for rotorcraft to operate efficiently in the NAS.

To develop a national system of public-use IFR heliports—Current design standards are being updated to include criteria for the design of IFR heliports. The primary responsibility for the development of public-use heliports rests with local communities, which have been actively exploring the potential for downtown access to the nation's air transportation system via urban heliports. To foster and facilitate accomplishment of the broad spectrum of tasks leading to a national network of urban heliports, the FAA has sponsored the National Prototype Heliport Demonstration Program. Four urban city-center heliports will be developed with all-weather capabilities, and will serve as the mechanism by which innovative procedures, systems, and facilities will be investigated.

To improve the effectiveness and efficiency of the certification of aircraft, equipment, and crews—This includes preparation for the certification of new technologies so that they can be placed quickly into safe, productive use. Safety must be ensured as new technologies are integrated into new rotorcraft and associated systems, and as crews are trained to use new capabilities.

A.3
Rotorcraft Evolution

The specific near, mid-, and far term evolution of rotorcraft operations and capabilities are detailed below.

A.3.1
Near Term (1986-95)

During the near term, conventional helicopters, as we know them today, will continue to grow in numbers, approaching the 10-15 thousand projected for the year 2000. Public acceptance will have increased as a result of a number of key factors. The National Rotorcraft Noise Reduction Program, under which manufacturers developed the analytic tools and data base necessary for the design of quieter helicopters, will produce improved machines. Concerted efforts by rotorcraft operators to exercise measures for reducing the impact of noise pollution, particularly through the Fly Neighborly Program of the 1980s, will further serve to promote public

acceptance. Ride quality improvements will be attained through design technologies for the refinement of higher harmonic control, a bearingless main rotor, and integrated structures/propulsion/controls.

In addition, technology will have provided for substantial improvements in control systems, stability and control augmentation, cockpit displays, and low-airspeed sensing to reduce crew workload for minimum IFR airspeeds, typically of 30 knots. True Category A performance will have been achieved through the use of more powerful engines. Manufacturers will have perfected the design of full-authority digital engine control systems (FADECs) and over-power indicators for use by multi-engine rotorcraft with one engine inoperative during critical phases of flight. As a result of low IFR speed and reserve power capabilities, helicopters will possess the necessary performance to conduct very steep decelerating approaches to a 50-foot hover, making it possible to access even the most difficult city-center locations. The Microwave Landing System (MLS) will have been deployed and will be available at numerous urban heliports. A collocated back azimuth antenna will provide for positive course guidance during missed approaches and departures, substantially reducing the amount of protected airspace required for urban heliports.

A civil version of the military tiltrotor aircraft will be certified. The V-22 (initially known as the JVX) will be produced in a 25- to 30-seat civil version. Cruise speeds of 300+ knots will be possible, economically increasing the feasibility of longer stage lengths for rotorcraft flights. Reduced noise signatures will further enhance the ability of the tiltrotor to operate into urban IFR heliports.

Low-altitude communications will be further improved by the use of HF techniques. These techniques will supplement VHF-AM voice service in selected areas, where further expansion of the VHF system cannot be economically justified.

The Global Positioning Satellite (GPS) navigation system, deployed during the late 1980s, will provide for low-altitude area navigation and serve as a sole means for navigation. Provision will be made for the widespread use of GPS for nonprecision approaches.

In selected areas, low-altitude surveillance will be accomplished by using dependent surveillance techniques. Loran C and GPS-based dependent surveillance will have been implemented for offshore areas. Dependent surveillance target tracking and controller display will have been integrated into the NAS en route system. ATC procedures will have been established that will permit ATC separation standards to be reduced through the use of such systems as Loran C and GPS-based dependent surveillance.

ATC automation will permit low-altitude direct random routing. The increased level of ATC automation, coupled with the ability to track aircraft at low altitudes and in remote areas, will provide a means of allowing short-haul rotorcraft flights directly from point to point. Since the primary prerequisite for low-altitude dependent surveillance is communications, most heliports will be able to obtain full ATC services for IFR operations. ATC planning criteria and procedures will be developed for en route and terminal operations, optimizing efficiency for rotorcraft users, as well as for other NAS users.

Traffic Alert and Collision Avoidance System (TCAS) equipment will have been adapted for rotorcraft. This version of TCAS will be suited for low-speed, low-altitude operations in high multipath environments. Equipment will be capable of handling higher traffic densities and rapid aircraft heading changes. Rotorcraft users are expected to equip with TCAS because of the large amount of proximate Visual Flight Rules (VFR) in urban areas; the limited availability of full ATC services in remote areas and at some heliports will make TCAS attractive as well.

Improved weather observations, essential for IFR operations at heliports, will be provided. Compact visibility sensors will provide visibility information. Later in this period, finer granularity reports of ceiling and visibility will be generated to support lower instrument minima at IFR heliports. Other sensors will provide information on severe weather phenomena to increase safety.

A.3.2
Mid-Term (1996-2005)

In the mid-term, the tiltrotor concept will be enhanced. Upon transitioning to turboprop cruise (approximately 300 knots), rotor blades will be folded back to reduce drag. Turbine engines, which provide shaft power during hover and turboprop forward flight, will simultaneously transition to turbofan mode. The folding tiltrotor concept will depend on the refinement of convertible engines—those capable of transitioning from turboshaft to turbofan and back again—developed in the near term. Folding tiltrotor aircraft will be capable of cruise speeds in the 500 knot range, again expanding the economic feasibility of longer stage lengths while preserving the capability to access urban heliports.

Further advances in stability and control systems design will result in a few aircraft with an IFR hover (minimum IFR airspeed of zero knots) capability. Quad-redundant control systems with asynchronous architectures will be common. These aircraft will form the backbone of urban air transportation, being able to access many new urban heliports, unlike current rotorcraft.

Simulators will, by this time, play a major role in the certification of rotorcraft. In many cases, handling qualities and crew-machine interface issues will be resolved and certified solely by simulator, which will also be the primary means of conducting training. The use of simulators, which started in the near term, will require the improvement of fidelity (motion, visual, and aural) at speeds down to hover for application to the newer aircraft now available.

Urban IFR heliport networks will be established in 25 to 30 cities. Service at downtown urban heliports is expected to be comparable to that found at airports. In addition to service reliability in bad weather, full passenger terminal facilities will be common. Newer forms of rotorcraft will carry more passengers from city-center to city-center points, without passing through airports. The national network of heliports will accommodate higher volumes of private and air taxi (unscheduled) aircraft, since these urban locations will be hub-and-spoked to locations not served by scheduled carriers. Rural areas will be able to obtain access to the national air transportation network with minimal investments in heliports, instead of the more substantial investments required for airports.

ATC planning and procedures development will accommodate new types of aircraft, such as the folding tiltrotor. New concepts may permit cruise speeds to be used at lower altitudes to increase system capacity, increase efficiency, and further reduce transit time for passengers. Flight planning will use higher orders of automation. User systems will interface with NAS flight planning facilities and automatically assess flight plans based on time, fuel-efficient profiles, distance, and altitude tradeoffs.

Communications at low altitudes will be accomplished through satellites. Satellite service will be available for single-channel data and limited voice. Cockpit voice synthesizers and recognition devices will simplify the transition to greater use of data communications between aircraft and ground facilities. Additional communications will be available, particularly in urban areas, through terrestrial packet radios, which will utilize portions of the existing aeronautical VHF spectrum.

A number of significant navigation developments will yield new operational benefits. Differential navigation techniques will become feasible, particularly with the availability of data communications service at low altitudes. Differential GPS, for instance, will provide better-than-nonprecision approach minima and airspace protection. Altimetry accuracy will increase. The use of altitude information in conjunction with 2D area navigation will provide minima approaching those of Category I today. These advanced navigation capabilities, together with accurate system time, will provide the foundation for 4D area navigation. This capability will in turn set the stage for time-based ATC operations.

A.3.3
Far Term (2006-2015)

In the far term, other high-speed rotorcraft will evolve. The X-wing, which uses circulation control to change the aerodynamic shape of the rotor airfoil, will be capable of cruise speeds in the 500 knot range. The X-wing, like the folding tiltrotor, depends on convertible engine technology. Take-off and transition to forward flight are accomplished in a manner similar to that of a conventional helicopter. Then, the main rotor is gradually slowed and stopped as the turboshaft engine converts to a turbofan engine. The circulation on the stationary rotor is modified to reverse the airfoil shape on the left set of blades. Other concepts, such as the coaxial rotor advancing blade aircraft, may also materialize, with added features, such as a pusher fan, for full cruise speeds in the same range as those of the X-wing. Heavy-lift (150,000 pounds) and large passenger-carrying vehicles operating in speed ranges of 200-550 knots may be produced, depending on technology and market demand. These and other forms of aircraft are likely to have varied operating envelopes and fuel-efficient profiles, and should be considered for accommodation in the future NAS.

Automation in the NAS is expected to reach a level that will permit pilotless vehicles for selected applications. Initially, cargo transport, surveillance, fire fighting, law enforcement, and similar users will be able to operate fully automated aircraft (with no crew). Other applications will be considered for fully automated flights as such systems prove themselves over time.

Communication, navigation, and surveillance may be combined into a single satellite-based system for civil users. Low-altitude users would be integrated naturally into the NAS since one system would respond to the needs of all users.

With these developments in rotorcraft, the potential for rapid expansion of the nation's air transportation system will increase several-fold, since reliable service to small communities will be obtainable at minimal cost.

A.4
Summary

All facets of the rotorcraft industry are changing rapidly. With the rotorcraft itself, research and technology promise radical changes and improvements in all components. These advancements will help sustain U.S. aeronautical leadership into the next century. Nationally, they will allow the rotorcraft to reach its full potential in meeting our transportation requirements. These opportunities challenge the nation's creativity, but hold the promise of tremendous public benefits.

Appendix B
DOD Perspective of the NAS

Like other aircraft operators, both private and commercial, the Department of Defense (DOD) routinely uses the services of the NAS. Unlike other users, however, the DOD also provides air traffic control (ATC) and navigational services in the NAS, and does so for both civil and military aircraft. Tables B-I through B-III provide a summary of DOD and FAA ATC activities and clearly indicate the substantial role played by the DOD in Federal air traffic service endeavors; this role is recognized explicitly in NAS R,E&D planning.

The development of all current and future DOD requirements is based on the following fundamental principles:

- The military will continue to operate cooperatively with all other system users. The NAS therefore meets and will continue to meet unique military needs that differ from the routine demands placed on the system by point-to-point civil operators.
- ATC services within the NAS will continue to be provided in common to both civil and military aircraft by a mix of FAA and DOD facilities. While the NAS is primarily configured to support point-to-point civil activity, the FAA supports military air operations where the services of military Air Traffic Control Facilities (ATCFs) or Military Radar Units (MRUs) are not available.
- The NAS includes military ATCFs, whose services will continue to be available to both civil and military aircraft. Such facilities ensure the availability of a cadre of trained and qualified military controllers for assignments outside the conterminous United States.
- In addition to ATC services, the NAS structure supports overall national defense objectives. These include operation of the nation's air defense system, maintenance of airspace for special use by military aircraft, maintenance of an integrated national communications system, the conduct of military exercises and deployment, and other such activities. In this regard, the NAS is capable of continued operation following transition to a wartime posture, at a high level of survivability and redundancy.

The NAS satisfies four categories of operational requirements:

DOD Aircraft Operations—Encompasses requirements associated with military flight activity within that airspace generally considered as en route, as well as the transition between airspace designated for military use and the FAA terminal/en route airspace, and between military terminal areas and the FAA en route/terminal airspace.

DOD ATCFs—Encompasses requirements associated with the operation of military and civil ATCFs, and the provision of common services to military and civil aircraft.

Air Defense System Operation—Encompasses requirements associated with the operation of MRUs; the identification of aircraft operating in and through Air Defense Identification Zones (ADIZs); and the overall efficient operation of the Air Defense System.

Other Areas of DOD Activity—Encompasses requirements associated with integration of the national communications system, transition of the NAS to a wartime posture, priority accommodation of unique military operations when necessary, overall interoperability of civil and military assets, and NAS survivability.

Tables B-IV and B-V present the DOD perspective of R,E&D objectives during the near, mid-, and far terms.

Table B-I
Air Traffic Control Operations Handled (CY83) (millions)

DOD*	CONUS		Overseas		Total		DOD Operations
	Operations	% Civil Aircraft	Operations	% Civil Aircraft	Operations	% Civil Aircraft	% of Total
USAF	11.2	22.8%	2.2	19.4%	13.4	22.2%	12.0%
USA	6.7	3.5%	0.6	2.1%	7.3	3.3%	6.5%
USN	7.5	11.0%	0.7	8.8%	8.2	10.7%	7.5%
TOTAL	25.4	13.4%	3.5	13.2%	28.9	13.4%	26.0%
FAA	82.7				82.7		74.0%

Total Federal ATC operations: Worldwide—111.6, CONUS—108.1
*DOD figures do not include 1.5 million USN carrier operations.

USAF = U.S. Air Force
USA = U.S. Army
USN = U.S. Navy

Table B-II
Federal Navigational Aids Operated (CY 84)

DOD*	CONUS	% of CONUS Facilities	Overseas	Total	% of Facilities Worldwide
USAF	236	10.0%	73	309	12.0%
USA	100	4.2%	23	123	5.0%
USN	93	3.9%	58	151	6.0%
TOTAL	439	18.1%	154	503	23.0%
FAA	1,935			1,935	77.0%

Total Federal Navigational Aids: Worldwide—2518, CONUS—2364
*Includes only shore-based, fixed DOD facilities. Does not include ship-board USN or tactical USA-USAF facilities.

Table B-III
Staffed Federal Air Traffic Control Facilities (CY 84)

DOD*	CONUS	% of CONUS Facilities	Overseas	Total	% of Facilities Worldwide
USAF	150	15.0%	59	209	18.5%
USA	85	8.0%	38	123	10.9%
USN	101	10.3%	12	113	10.0%
TOTAL	336	33.0%	109	445	39.0%
FAA	687**			687	61.0%

* Shore-based only, fixed facilities.
** Does not include Flight Service Stations.

Table B-IV
Special Use Airspace Utilization

Themes	Near Term 1986-1995	Mid-Term 1996-2005	Far Term 2006-2015
Increased timeliness and flexibility in use of special use airspace (SUA) • Reduce approval time for use of non-rule making SUA • Coordinate civil/DOD use of SUA • Develop flexible use of SUA to accommodate mission requirements • Improve control of non-rule making SUA by using real-time entry/exit control • Review SUA to allow for better DOD/civil use	Accommodate SUA reservations received from DOD users within 60 minutes of request: • Include user-preferred routes • Offer flexible routings to SUA if preferred routing is not available Coordinate and re-position as necessary air refueling tracks Coordinate DOD/civil use of low-level airspace so as to minimize interruption of DOD training and civil airspace use Maintain communications with aircraft on military training routes Provide capability for satellite-dependent surveillance of DOD/civil aircraft	Accommodate access to SUA within 30 minutes of request ACFs and flow control accommodate full use and timely access to SUA Accommodate large-scale increases in low-level training	Accommodate low-level VFR operations as normal rather than requiring special handling

Table B-V
Other DOD Requirements for Civil ATC Services

Themes	Near Term 1986-1995	Mid-Term 1996-2005	Far Term 2006-2015
Increase support to evolving DOD operations: • Reduce runway separation • Reduce standard IFR separation • Reduce separation criteria between runways • Reduce controller and pilot phraseology	Accommodate surge generation of departures and arrivals to include a mix of fighter and heavy aircraft Refine terminal procedures to accommodate helicopter-only approaches	Accommodate supersonic low-level flights	Expand permanently delegated airspace boundaries to accommodate DOD requirements
• Improve access of offshore carrier aircraft to the NAS		Expand system support to accommodate offshore carrier operations	Accept long-range radar returns, JTIDS/data link, and SATCOM to ensure constant awareness of planned versus actual positions/intentions of offshore aircraft
• Incorporate new DOD weapons systems	Accommodate missiles, remotely piloted vehicles, laser systems, forward-looking infrared systems, and stealth aircraft, to include special routing and standard safety parameters.	Improve incorporation of new DOD weapons systems	
Increase support of GPS and RNAV	Incorporate GPS as part of the NAS through common computer acceptance of GPS reference sources (GPS will be primary DOD NAVAID)	Accommodate differential GPS as a precision approach capability for DOD aircraft For oceanic flights, use GPS for positioning and automatic dependent surveillance for reduced separation and increased throughput	Increase use of GPS and data link to provide new surveillance capability
Improve flexibility of DOD operations in the civil terminal environment • Implement improved climb/descent profiles for fighter aircraft	Increase automation in the terminal and en route environments to permit improved use of terminal airspace for DOD VFR aircraft Accommodate rapid climb/descent when exiting and entering the terminal environment, especially for tactical fighter aircraft	Establish real-time climb and descent corridors to accommodate high-altitude egress/ingress requirements of DOD aircraft	

Appendix C
Advanced Technology Air Transport Aircraft

C.1
Introduction

Since the early days of aviation, the U.S. has held a position of preeminence in aeronautical technology. However, the present intense global competition in high technology clearly poses a serious challenge to the U.S. in this field. The erosion of U.S. leadership in aviation could seriously weaken our economic and strategic future, and would significantly reduce the vitality of our industry in the global market. The White House Office of Science and Technology Policy (OSTP) recently conducted a comprehensive review of the state of aeronautics research to identify ways of ensuring clear-cut U.S. superiority in civil and military aircraft technology. The OSTP recognized the opportunities offered by several segments of aeronautics technology, including the following:

Advances in aerodynamics—could result in drag reduction, better vortex management, and integration between aero and propulsion systems.

Advances in propulsion technology—may lead to increased fuel efficiency, higher thrust-to-weight ratios, longer engine life, and lower cost for conventional engines, as well as the economical development of supersonic and hypersonic ramjets and a range of variable-cycle engines.

Advanced structures—will include adaptable, fault-tolerant topologies, and may be formed with improved metal matrix or carbon-based high-temperature composites.

Guidance and control systems—may be designed to permit optimal allocation of man/machine roles and distributed, fault-tolerant architectures.

Information processing technology—should continue its rapid advances and should revolutionize the entire spectrum of aviation technology.

The OSTP identified specific goals in the three areas of subsonic, supersonic, and transatmospheric aircraft that government, industry, and academia should pursue to capitalize on foreseen technology advances. The challenge to the NAS is to incorporate an efficient means of integrating new aircraft technologies so that effective use can be made of their unique characteristics.

C.2
Specific Goals

C.2.1
Subsonics Goal

This near-term goal envisions an entirely new generation of fuel-efficient subsonic aircraft operating in a flexible and modernized NAS. It also envisions the development of advanced military airlift capabilities, long-endurance aircraft, and advanced rotorcraft. Such advanced subsonic aircraft may dominate civil aviation around the world well into the next century. This goal is crucial because its accomplishment can generate the private-sector resources necessary for industry to pursue follow-on opportunities in supersonic and transatmospheric flight.

Technologies that are integral to the development of subsonic aircraft include laminar flow control for drag reduction, all-composite high-strength structures, super bypass and propfan engines, fully integrated flight controls, and flight management computers. New aircraft will also include fuel-efficient and less expensive general aviation (GA)/commuter aircraft, rotorcraft, Short Take-Off and Landing (STOL) and Vertical Take-Off and Landing (VTOL) aircraft, and transport aircraft.

The subsonics goal can thus be characterized as follows:

- It envisions developing technology for an entirely new generation of fuel-efficient, affordable U.S. aircraft operating in a modernized NAS. This technology will supersede existing subsonic technology to capture immense civil aircraft market opportunities.
- It supports the development of advanced military aircraft capabilities.
- Its accomplishment requires the acceleration of key technology advances so that they will be developed by 1995 for application well into the next century.

To maximize the efficiency of these aircraft, the ATC system should permit the flying of direct routes and provide automation to increase system capacity.

C.2.2
Supersonics Goal

The capability of sustained supersonic cruise is vital in military aircraft for survivability, long-distance responsiveness, and basing flexibility. It also offers significant strategic and economic advantages to the U.S. in its trade and alliances in the Pacific region, presently constrained mainly by distance. Since the termination of the U.S. Supersonic Transport (SST) Program in the early 1970s, advances have been achieved in the areas of single-crystal turbine blades, better coatings, and improved cooling methods. The application of these technologies can form a strong basis for renewed SST efforts.

The application of powder metallurgy technology and superplastic-forming techniques to load-carrying structures, along with new thermoplastics, carbon-carbon, and metal matrix materials, will also yield significant benefits for all classes of military and civilian supersonic aircraft. Additionally, fault-tolerant computers that provide load alleviation and dynamic damping, coupled with the cooler structure allowed by supersonic laminar flow, will significantly reduce the aircraft weight-to-payload ratio as compared with earlier supersonic transports. The advent of powerful computer systems will make possible the computation of complex flows and the optimization of configurations that extend the regions of supersonic laminar flow. A complete understanding and verification of the potential for supersonic laminar flow is critical for sustained cruise speeds that would make possible both military and civil aircraft operations at triple the fuel efficiency of today's supersonic technologies. Combined with other supersonic advances, this technology can also substantially reduce the overpressures contributing to sonic booms.

Creative integration of these technologies could provide the U.S. and its Pacific allies with a transportation system linking the farthest reaches of the area in four to five hours, while providing the military with vitally needed mission enhancements in survivability, long-distance responsiveness, and basing flexibility.

Thus, the supersonics goal can be characterized as follows:

- It involves the development of pacing technologies for sustained supersonic cruise capability.
- It makes possible linking of the farthest reaches of the Pacific Rim in four to five hours, recognizing growing U.S. strategic and economic interests with partnership potential.
- It provides the military with enhancements in survivability, long-distance responsiveness, and basing flexibility.
- It supports applications through much of the next century.

NAS services should be available to permit user-preferred trajectories for these vehicles.

C.2.3
Transatmospherics Goal

A transatmospheric vehicle will have the capability of routine cruising and maneuvering into and out of the atmosphere, rapid low earth orbit missions, and rapid transportation between earth destinations from conventional runways. It thus involves the areas of both aeronautics and space transport. Because these two areas are rapidly converging, a basic understanding of the transatmospheric environment must be achieved in the near term. This understanding will permit the clear definition and selection of specific technical areas that may influence future national options in space and aeronautics. The development of transatmospheric flight capabilities will be made possible by technical advancements in such areas as subsonic, supersonic, and hypersonic aerodynamics; blended body concepts; artificial intelligence; hybrid air-breathing engines; and materials.

This technology is clearly important for preserving future U.S. military options, and must not be overlooked.

The transatmospherics goal can thus be characterized as follows:

- It pursues research toward the capability to cruise and maneuver into and out of the atmosphere routinely with take-off and landing from conventional runways.
- It builds on progressive subsonic, supersonic, and hypersonic advancements in aeronautics technology, as well as Space Shuttle experience.
- It influences long-range options for both aeronautics and space.
- It leads to military and civilian 21st century leadership in technology.

In addition to providing NAS services on user-preferred trajectories, the FAA can support these national goals by providing the facilities, equipment, and procedures that would be needed by advanced subsonic, supersonic, and transatmospheric vehicles. If pace is kept with the advances in these technologies, new aircraft and equipment can be certified and accepted within the NAS in a timely manner.

Appendix D
Glossary

Air Traffic Clearance—An authorization by air traffic control for an aircraft to proceed within controlled airspace, according to flight plan, or as assigned or restricted. The purpose is to prevent collisions between known aircraft and to expedite their movement.

Automatic Dependent Surveillance—Surveillance of an aircraft based on position data obtained and reported automatically by the aircraft.

Category A Aircraft—An aircraft with a final approach speed of less than 91 knots.

Category I, II, III Approaches—Type of ILS/MLS approaches as defined by minimum surface weather conditions. The requirements are established by the ground equipment, runway lighting, terrain, and air crew proficiency for equipped aircraft.

Category	I	II	IIIA	IIIB	IIIC
Minimum Ceiling (feet)	200	100	50	35	0
Minimum Forward Visibility (feet)	2600	1200	700	150	0

Conflict Alert—An alert issued by the air traffic control system to the controller when the flight paths of two or more aircraft are likely to violate separation standards.

Conflict Probe—An automation algorithm that uses the best available aircraft intent data (e.g., flight plans, clearances, flight path intent data from the aircraft's flight management system, and winds aloft and weather forecasts) to determine if a planned flight profile will be clear of other traffic, special use airspace, and terrain.

Conflict Resolution Advisory—A function of the Automated En Route ATC (AERA) system designed to provide assistance to en route radar controllers in resolving potential conflicts when violation of separation standards is about to occur.

CONUS—Contiguous or Conterminous United States.

Dependent Surveillance—Surveillance of an aircraft based on position data obtained on board the aircraft and reported to ground-based air traffic control.

Direct Support of NAS Plan—Projects that are specifically identified in the NAS Plan.

Far Term—A period of time in the Research, Engineering and Development (R,E&D) Plan including and between the years 2006 and 2015.

Flight Level—A level of constant atmospheric pressure related to a reference datum of 29.92 inches of mercury stated in three digits that represent hundreds of feet, e.g., FL250 represents a barometric altimeter indication of 25,000 feet.

Flight Management—A tactical function of the air traffic control system designed to provide individual flights with services needed to accomplish their missions safely, efficiently, and with minimum constraints.

Flight Plan—Specified information related to the intended flight of an aircraft that is filed orally or in writing with a Flight Service Station (FSS) or an air traffic control facility.

Flight Plan Conflict Probe—A function of the Automated En Route ATC (AERA) system designed to predict violation of separation standards on the basis of current and proposed clearances.

Flight Plan Filing—The submission of a flight plan to an air traffic control facility.

Flow Management—The ATC function that will integrate the traffic management (strategic) and the flight management (tactical) functions, and will automatically issue conflict-free clearances to users for any trajectories of their preference.

4D Clearance—An air traffic control clearance issued in terms of aircraft arrival at a geographical position at a specified time.

4D Equipped Aircraft—An aircraft carrying 4D navigation equipment on board.

Hypersonic—Relating to speeds of greater than five times the speed of sound.

Inflight Access—Access to an airborne aircraft.

Instrument Approach Procedure—The orderly transfer of an aircraft under Instrument Flight Rules (IFRs) from the beginning of the initial approach to a landing, or to a point from which a landing may be made.

Loran C—Long-range navigation aid using low frequency signals received from master/slave pairs of ground transmitters. Two or more master/slave pairs are used to compute position using airborne equipments.

Mid-Term—A period of time in the Research, Engineering and Development (R,E&D) Plan including and between the years 1996 and 2005.

Minimum En Route Altitude—The lowest altitude between radio fixes which assures acceptable navigational signal coverage and meets obstacle clearance requirements between those fixes.

Mode S Data Link—A cooperative surveillance and communications system designed to support air traffic control and provide other data link services, such as weather information, directly to the cockpit.

NAS Enhancement—Projects that are characterized by the development of new procedures, extensions of NAS software and hardware, and the development of more accurate and accessible flight planning data bases.

NAS Plan (F&E)—The FAA plan for modernizing and improving the air traffic control and airway facilities services through the year 2000 in terms of the new facilities and equipments to be acquired.

Near Term—A period of time in the Research, Engineering and Development (R,E&D) Plan including and between the years 1986 and 1995.

New Initiatives—Projects that apply emerging technology and concepts to communication, navigation, and surveillance services; airport and terminal area capacity; flexible routings; and support of high performance aircraft, for application primarily after the year 2000.

Nonprecision Approach—A standard instrument approach procedure in which only lateral guidance is used by the aircraft; that is, vertical guidance information is not provided other than from an altimeter.

Oceanic Airspace—The airspace beyond CONUS where control of aircraft is performed at oceanic control positions within coastal Air Route Traffic Control Centers (ARTCCs) or other air traffic control facilities.

Precision Approach—A standard instrument approach procedure in which an electronic glide slope is provided, such as in Instrument Landing System (ILS) and Microwave Landing System (MLS) approaches.

Primary Surveillance Radar—Ground-based radar that performs surveillance using reflected signals from aircraft surfaces.

Scheduling—The assignment of unique fix-time schedules to each aircraft in a sequence.

Secondary Surveillance Radar—ground-based radar that performs surveillance using aircraft beacon transponder replies and information encoded therein.

Sector Workload Factor—A performance measure of the tasks performed by ATC personnel in controlling air traffic within a sector for a specified time interval. The parameters that determine this factor include, among others, the average number of controlled aircraft expected in the sector, the number of aircraft conflicts predicted to occur, the number of planned actions predicted to be initiated in response to the above conflicts, and the total number of aircraft expected to enter the sector within the time interval.

Separation Standards—The rules that describe the spacing of aircraft, imposed to achieve safe and orderly movement in flight and during landing and take-off.

Sequencing—The arrangement of a number of aircraft in a sequence according to the order in which they should land.

Supersonic—Relating to speeds of from one to five times the speed of sound.

Sustaining R,E&D Activities—Aviation security, aircraft safety, airport and aviation medicine projects that are sustained principally in support of certification and standards activities.

System Studies—Projects that explore new concepts and technology to improve the NAS. The output of these projects are New Initiative projects to be included in future updates of this plan.

Terminal Airspace—Airspace delegated to a Terminal Radar Approach Control (TRACON), Terminal Radar Approach Control in the Tower Cab (TRACAB) or other airport tower for control.

Time-based ATC—Air traffic control services recognizing time as a fourth independent parameter in addition to the three spatial coordinates.

Time Navigation—Navigation of an aircraft enabling it to meet specified speed and fix-time schedules.

Traffic Demand—User requests for departure or landing at airports, and for holding in or transiting through a portion of airspace.

Traffic Management—A strategic function of the air traffic control system designed to match traffic demands to available terminal, en route, and oceanic sector capacities.

Transatmospheric Flight—Flight that extends above the earth's atmosphere.

User-Preferred Trajectory (UPT)—The route defined by the aircraft in terms of three-dimensional flight paths, and speed and fix-time schedules.

Appendix E
Acronyms

AAS	Advanced Automation System
ADIZ	Air Defense Identification Zones
ADS	Automatic Dependent Surveillance
AERA	Automated En Route ATC
AGL	Above Ground Level
AM	Amplitude Modulation
ARTCC	Air Route Traffic Control Center
ASDE	Airport Surface Detection Equipment
ATC	Air Traffic Control
ATCF	Air Traffic Control Facility
CNS	Communication, Navigation, and Surveillance
CONUS	Contiguous or Conterminous United States
4D	Four-Dimensional
DOD	Department of Defense
FAA	Federal Aviation Administration
FADEC	Full-Authority Digital Engine Control
FANS	Future Air Navigation Systems
FSAS	Flight Service Automation System
FSS	Flight Service Station
GA	General Aviation
GPS	Global Positioning System
HF	High Frequency
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INS	Inertial Navigation System
JTIDS	Joint Tactical Information Distribution System
MLS	Microwave Landing System
MRU	Military Radar Unit
NADIN	National Airspace Data Interchange Network
NAS	National Airspace System
NEXRAD	Next Generation Weather Radar
NWS	National Weather Service
OSTP	Office of Science and Technology Policy
R,E&D	Research, Engineering and Development
RNAV	Area Navigation
SST	Supersonic Transport
STOL	Short Take-off and Landing
SUA	Special Use Airspace
TCAS	Traffic Alert and Collision Avoidance System
TRACAB	Terminal Radar Approach Control in the Tower Cab
TRACON	Terminal Radar Approach Control

UPT	User-Preferred Trajectory
USA	United States Army
USAF	United States Air Force
USN	United States Navy
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	VHF Omnidirectional Range
VTOL	Vertical Take-off and Landing